FIXTURES FOR TURNING, BORING AND GRINDING

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TOOL ENGINEERING

FIXTURES FOR TURNING, BORING AND GRINDING

BY

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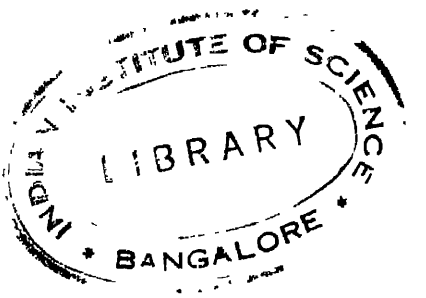
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PREFACE

In this book, which is the second volume on the subject of tool engineering, we discuss the factors of importance which affect the design of tools and fixtures for turning, boring and grinding operations. We have followed the same general idea of dealing with fundamental points in design in order that the reader may understand thoroughly *the reasons why* certain things are done and having thus established a substantial foundation he may develop his ideas in a thoroughly practical manner.

The first volume published covered the subject of tool engineering as applied to the design of jigs and fixtures, taking up the various problems systematically and illustrating the points involved in such a way as to bring out the mechanical principles which apply to each particular case.

The third volume will deal with the design of punches, dies and gages used in production work, analyzing the subject matter in the same manner which has been followed in the first two volumes.

ALBERT A. DOWD.
FRANK W. CURTIS.

NEW YORK, N. Y.
January, 1923.

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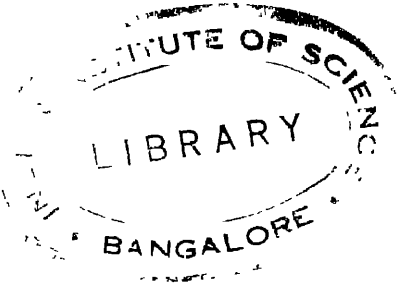
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TOOL ENGINEERING

FIXTURES FOR TURNING, BORING AND GRINDING

CHAPTER I

CONSIDERATION OF TURRET AND ENGINE LATHE TOOLING

FACTORS TO BE CONSIDERED—SELECTION OF MACHINES—IMPORTANT POINTS IN DESIGN—MACHINE REFERENCE SHEETS—TYPES OF TURRETS—TYPES OF CROSS-SLIDES—METHODS OF HOLDING WORK—LOCATING AND SUPPORTING WORK—DESIGNING FOR ECONOMY—FACTOR OF SAFETY

In discussing tooling methods for turret and engine lathes, we are taking up a subject radically different from any of those mentioned in the preceding articles. Both turret and engine lathes are used extensively in manufacturing and the tooling for these machines is of great importance in its application to high-class production methods. The average tool designer is usually somewhat "out of his element" when called upon to design fixtures and tools for turret lathes. It is of importance therefore to consider not only the design of tools and fixtures but also the construction and operation of the machines used for the work.

The possibilities of the machines from a production standpoint are so great that a clear understanding of the class of work to which they are suited is one of the primary requirements when dealing with their application to production processes. Many factors affect the methods used on this class of work so that it is advisable to specify some of these in order to understand their importance thoroughly.

In turret and engine lathe work we must always consider: (A) the work; (B) the method of holding, and (C) the cutting tools. By separating them in this manner it will be easier to

understand various points in connection with each. For example, speaking of the work, it may be made from bar or cut-off stock, it may be a casting or a forging, regular or irregular, cylindrical, tapering or rectangular; it may be heavy and cumbersome, or it may be light and fragile. These matters all have an effect on the method used to hold the work for the cutting operations. The design of the holding device is effected strongly by the size, shape, and general contour of the piece that is to be machined. The selection of the machine tool on which it is to be manufactured is also governed to some extent by the same items.

Standard types of cutting tools are used for certain kinds of work while for other varieties and classes of work special tool equipment is necessary. It will be seen from the foregoing that there are many points of importance which must be thought of in connection with the design of tools for turret lathe work.

In considering the method of handling any piece of work we must first select the machine, then determine the method of holding and finally design the tools which will do the work. In order to avoid confusion we will consider these matters separately; taking up first various methods of holding different kinds of work. The points of importance to be considered in the design of holding fixtures are quite varied and we will therefore separate them as far as possible and mention important matters connected with each condition.

(1) The work may be a rough casting or forging or it may have been partially finished in a previous operation. If it is a rough casting it may be of regular shape such that it can be held by the outside or the inside in some variety of chuck, either by means of regular or special jaws. Again the casting may be rough and regular in shape so that it can be held with special chuck jaws, but it may also be so long that it requires additional means of support, provision for which may be made either on the body of the chuck or by means of a supplementary fixture on the machine.

(2) The work may be irregular so that it can not be held by chuck-jaws, in which case it will require a special fixture for holding. Occasionally fixtures of this kind require a great deal of care in their design, depending upon the nature of the work and its general shape as well as the machine operations that are to be performed upon it.

(3) If the work is thin and fragile, whether it is regular or irregular in shape and whether it is held by chuck jaws or in a special fixture, particular attention must be paid to the method of holding so that there is no possibility of distorting the work and causing inaccuracies in the finished product. Not only must the method of holding provide against this but also the action of the cutting tools must be considered so that the latter do not tend to distort the work during the process of machining.

(4) Work that has been finished in a previous operation may often require a special fixture in which suitable provision is made for locating from one or more important finished surfaces.

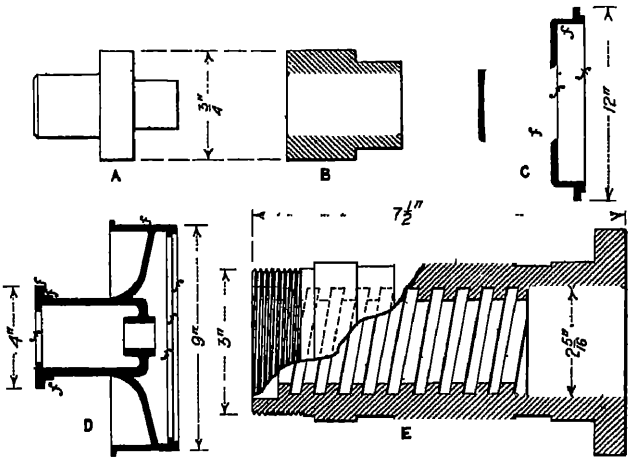


FIG. 1.—Examples of work suitable for turret lathes.

The foregoing points all have to do with the condition and general shape of the work but there are additional matters to be considered in connection with the design of holding devices which are applicable to practically all conditions. These points will be specified in detail later in this article.

Fig. 1 shows several examples of regular work suited to production on turret lathes. Examples *A* and *B* are made from bar stock with simple tooling of a standard nature. The work *C* is a casting of regular shape which can be held for machining in special chuck jaws and the work done in one operation as indicated by the *f* marks. The work shown at *D* can be held for the first operation in special chuck jaws while the second operation requires a locating device of special form. This piece

requires two operations to complete the turret lathe work. The example *E* is a bronze casting having both an internal and external thread. The inside thread should be cut by means of a chasing attachment and the external thread with a self-opening die. Two operations would be required for this piece of work.

These examples of turret lathe work have been given in order to show the great variety which can be handled on machines of

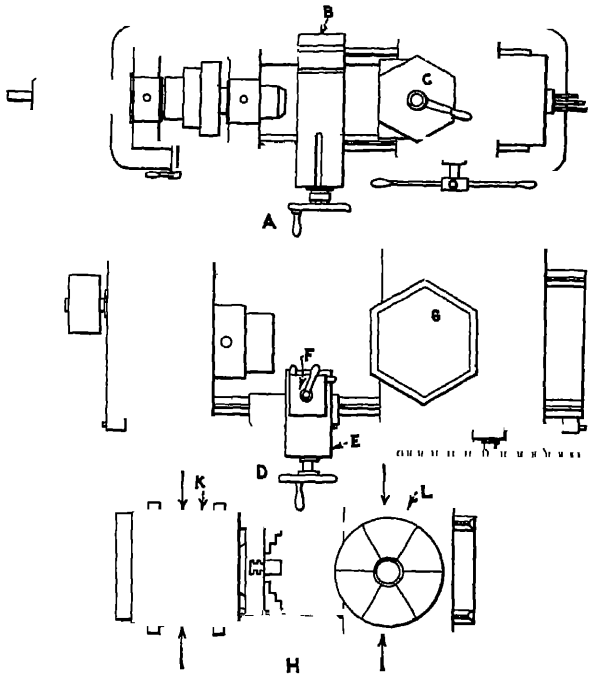


FIG. 2.—Representative types of turret lathes.

this kind. No attempt has been made to show irregular work which would require fixtures, as these will be taken up later in other chapters.

Selection of Machines.—In determining the type of machine most suited to a given piece of work it is necessary for the designer to have a general idea of the various types in common use. The diagrams shown in Fig. 2 are given in order to represent the operation features of several types of machines. All of these machines have somewhat different characteristics and for that

reason the diagrams are made in such a way as to bring out the points of difference and to show their effect on the design of tools and fixtures.

The example *A* is a plain turret lathe having a cross slide *B* extending entirely across the bed and a turret *C* mounted on an adjustable longitudinal slide. Chucks or fixtures can be attached to the spindle and tools for cutting off or forming can be applied to the cross-slide. Tools are also applied to the turret. In the example *D* we have an all-geared head machine with a cross-slide *E* which does not extend across the bed of the machine, but which is provided with an indexing turret toolpost *F* is which a number of tools can be placed to operate in sequence on the work. The turret *G* is mounted on a longitudinal slide and can be furnished with tools for various operations. The example at *H* represents several other types, one of which is provided with a cross-sliding head *K* which carries the spindle on which a chuck or fixture can be mounted. In this type of machine there is no regular cross-slide used and the facing operations on work are accomplished by the cross feeding movement of the head. Another type of machine has a stationary head while the turret indicated at *L* has a cross feeding movement. This machine also has no cross-slide. These diagrams of the various types of machines in common use will make it evident to the designer that the application of tools to various turret machines is governed to a considerable extent by the type of machine to which the tools are applied. The movements of the turret, cross-slide, and head are somewhat different in several machines, and as a consequence the tools which are applied to them operate differently according to the particular machine selected.

In the selection of a machine for the work, judgment must be used in order that the tool equipment may be the most efficient that can be designed. The capacity of a given machine should always be ample to handle the work but it may be found that one type is more suited to certain operations than another; hence the machine selected should be one that will give the most satisfactory results.

Machine Reference Sheets.—As there are so many different movements to be taken into consideration in the operation of a turret lathe, it is necessary to know the range of movement of cross-slide and turret in relation to the spindle. Also it is essential that the various machine dimensions which affect the design

of tools should be readily accessible. It is undesirable to go into the shop and measure up every machine to which tools are to be applied, therefore data sheets giving complete information regarding machine sizes, ranges and capacities

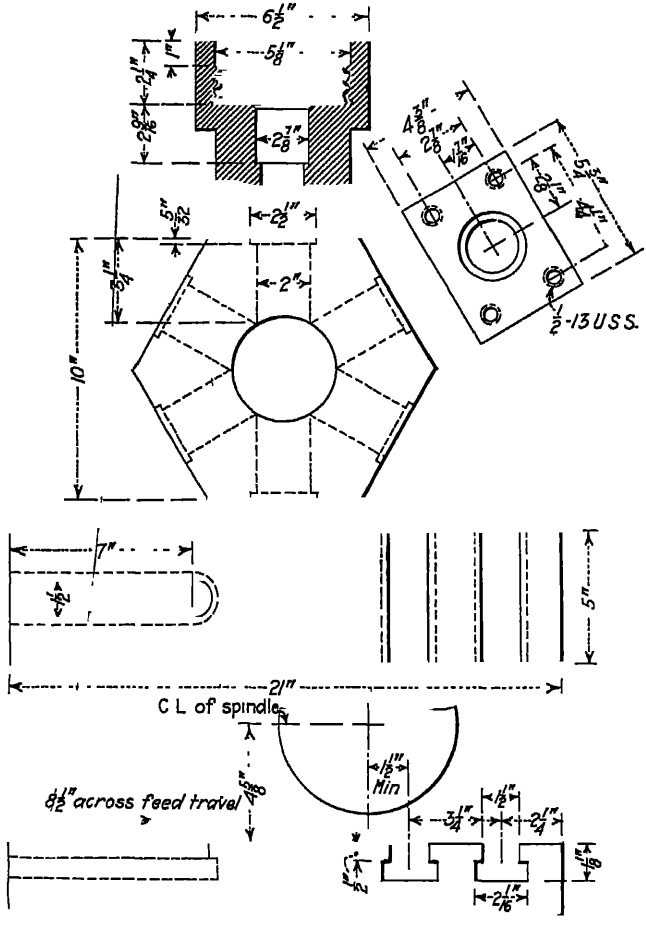


FIG. 3.—Data sheet for turret lathe

should be at hand for the tool designers ready reference.

Fig. 3 illustrates a data sheet for one certain size and variety of turret lathe. Attention is called to the various dimensions that are given on this sheet as they will all be found of value when designing tools or fixtures. Sheets of this kind should be pre-

pared for all production machines in the factory. They can be made on tracing cloth and blueprinted to form a data book for convenient reference. It is advisable to give the factory machine number on each of these sheets together with any information that will be of help in locating a particular machine in the factory.

Application of Fixtures and Tools.—In machining any piece of work on a turret or engine lathe we have first to provide a means of holding the work and next to furnish cutting tools which can be presented in sequence or combination to perform the

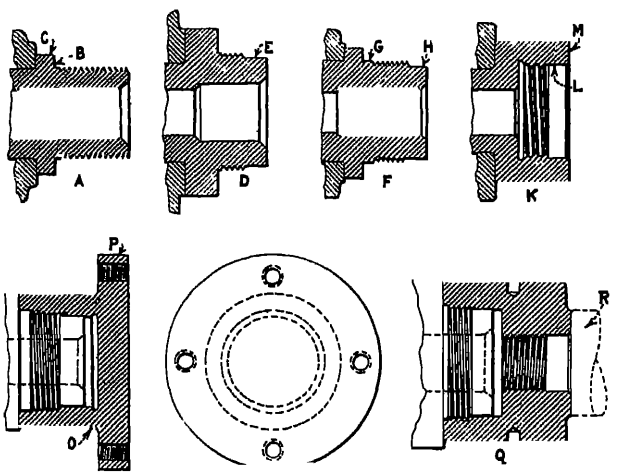


FIG. 4.—Types of turret lathe spindles.

various operations required. Fixtures are necessarily applied to the spindle of the machine while the cutting tools are used on the turret and cross-slide.

In the application of holding devices to the spindles of various machines the design of the spindle itself affects the fixture to some extent. Fig. 4 shows a number of types of spindles to which adapters, faceplates, chucks, collets and other holding devices can be applied. Any spindle which is designed to hold chucks or fixtures should be provided with a cylindrical portion for centering the chuck and a shoulder or surface for squaring it up in relation to the spindle. In nearly all cases the threaded portion provides a means of fastening the fixture and a cylindrical portion together with a squared up shoulder assists in truing up the fixture and taking the pull of the cutting tools.

In the example *A* the fixture screws on to the body of the spindle and is squared up by the shoulder *B* and centered by the outside diameter *C*. Example *D* is similar except that it has an additional bearing surface at *E*. Example *F* has a short threaded portion and two bearing surfaces at *G* and *H* in addition to the shoulder shown. The spindle shown at *K* is of a different variety as it is arranged so that the fixture screws into the female portion and obtains a bearing at *L* and also against the shoulder *M*.

In designing fixtures for use on turret lathe spindles it will be found good practice to fit the fixtures to an adapter such as that shown at *O* rather than to fit them to the spindle itself. The

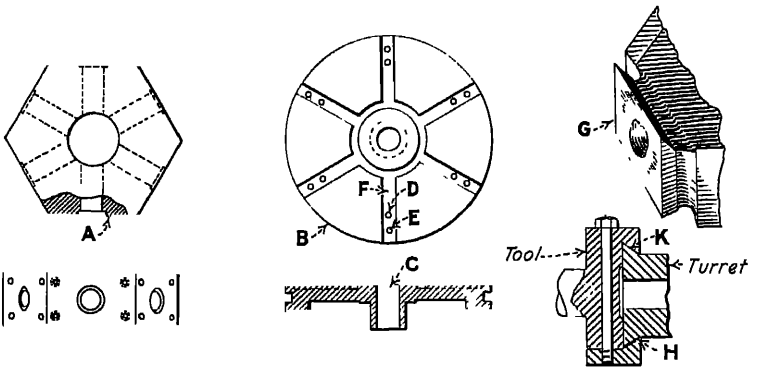


FIG 5.—Types of turrets

adapter is screwed directly to the spindle as indicated, and the fixture is made with a recess so that it will fit the flanged portion *P* on the adapter. By standardizing the adapters a great deal of fitting can be a avoided so that the fixtures will be cheaper in first cost and they will also be interchangeable on different machines by simply changing the adapters. This is sometimes an advantage when there is a possibility of changing a fixture from one machine to another.

The example shown at *Q* is an adapter hood which is screwed to the spindle and so arranged that a special plug or other device can be fastened into it as indicated by the dotted lines at *R*. Other matters connected with the application of faceplates to the spindle will be taken up later. The various examples of spindles shown here are given in order to illustrate the differences between them and to show how they must necessarily

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affect any holding devices or fixtures which are applied to them.

Turrets on various machines are quite different in construction so that the tools which are applied to them must be designed to suit the particular type of turret on which they are to be used. We shall not attempt to show each style but will simply indicate those that are quite different in general design and which therefore require a different method of fastening and locating on the turret. Fig. 5 shows three types of turrets. The example *A* is of hexagon shape with six flat faces, in the center of which there is a hole for the stem of the tool and also four tapped holes on the face to assist in fastening it in place. In the example *B* the tools are set on the flat surface of the turret *C* and fastened in place by two or more screws as indicated at *D* and *E*. The location of the tool is assured by means of the slot *F*. Another type of turret is shown at *G*. This form is dove-tailed at *H* and *K* so that the tools can be fitted to this portion and clamped firmly in position.

It will be evident from the foregoing description of the various types of turrets that the construction of tools to be applied to them would be quite different on account of the different methods of fastening and locating used. There are some other types of turrets besides those shown but their general construction is not greatly different from these examples and therefore it is unnecessary to illustrate them.

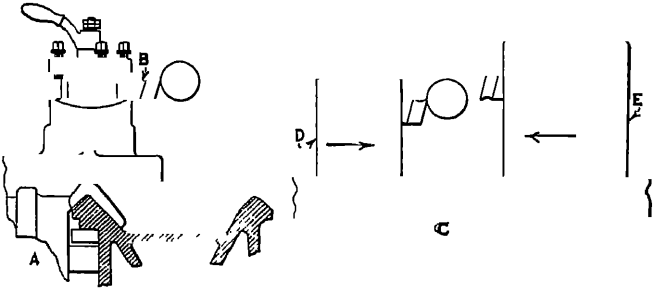


FIG. 6.—Types of cross-slides.

Types of Cross-Slides.—In designing cross-slide tools there are only two types of slides that need to be considered. One of these types, shown at *A* in Fig. 6, does not extend across the ways of the machine and the toolpost which is mounted on the slide is generally of the turret variety, having provision for

three or four tools as indicated at *B*. The other type of cross-slide, shown at *C*, extends entirely across the ways of the machine and is so arranged that standard or special toolposts can be applied to it as indicated at *D* and *E*. This particular form of cross-slide is in common use on operations requiring forming cuts and grooving and cutting-off operations. In case special tools are required the toolblocks can be designed to carry a group of tools at both the front and rear of the machine so that they will operate successively. The tools used for the cross-slide will be taken up separately in another chapter.

In pointing out the various factors of importance which must be considered in the design of holding devices for turret and engine lathe work, there are a number of matters which can be taken up to best advantage in the form of general notes. A number of these points are given herewith and more specific cases will be treated in their proper place.

(1) The production required, machine to be used, accuracy necessary in the product and material to be cut, must all be considered before attempting to design the holding fixture for any piece of work. The production required naturally affects the design of the fixture because a cheap fixture could be used when only a small number of pieces are to be machined, and no provision would need to be made for replacements in a fixture of this kind. But for high production work the fixture would need to be provided with refinements to permit of replacements of worn parts and to insure the required accuracy under severe service. The machines used for a given piece of work must be selected carefully, keeping in mind the size of the work, the range required and the accuracy necessary. The machines available in the factory should be listed and a judicious selection made of the machines most suitable for the work. The accuracy required in the finished product makes it necessary not only to consider the condition and quality of the machine tool but also makes it essential to provide accurate fixtures. If a high degree of accuracy is needed provision must be made so that the fixture can be adjusted to run true with the spindle. This is particularly desirable when the work is produced in large quantities.

The material that is to be cut influences the design of fixtures to some extent, but the shape of the work, its size and general characteristics are of more importance. A piece of work which is irregular in shape and which has thin sections will require a

very carefully designed fixture in order that there shall be no distortion of the work either while clamping or during the cutting action of the tools.

(2) Rigidity: Care must be taken that holding fixtures applied to the spindle of a machine are properly balanced so that they do not vibrate when in motion. It is sometimes necessary to use a counterpoise on fixtures which run at high speed. If the work that is to be held is long and the fixture used overhangs some distance beyond the end of the spindle, it may be found advisable to provide an "outboard bearing" in order to give the proper support. When anything of this kind is used it can be fitted to the ways of the lathe and adjusted so that it will greatly assist in preventing vibration in cases of an excessive overhang. In considering the matter of rigidity in connection with fixtures, the speed at which they will run should always be noted as it is evident that high-speed fixtures would need to be more carefully proportioned than those which run at slow speed.

(3) Location of work: If chuck-jaws are used for either inside or outside holding on rough work, they must be carefully proportioned so that their bearing on the work will not be too long. Jaws should be substantial in section in order to withstand the stresses of cutting, particularly when they overhang from the chuck some distance. If fixtures are used for rough castings care must be taken to see that the work locates on only three fixed points. The matter of location of rough castings has been taken up in one of the previous paragraphs. Selection of working points on which to locate castings must take into consideration the shape of the work that is being located and any parting lines, seams or fins on castings or forgings, in order that inaccurate work may not result from improper locating points. Occasionally pattern numbers on the outside of the casting cause trouble in location.

(4) Clamping methods: Many methods and devices for clamping have been mentioned previously and while the application to turret lathe fixtures may be slightly different from those which have been illustrated, the principles are the same in each case. It must be remembered however, that turret lathe fixtures revolve and therefore loose clamps should be avoided. Work should be supported as nearly opposite the clamps as possible in order that there will be no distortion of the work when clamping.

(5) Safety of the operator: As turret and lathe fixtures are applied to revolving spindles, care should be taken in the design to avoid the use of protruding screws, clamps or lugs so that the operator will not be endangered by such things catching on his clothing. It is important also to pivot any swinging members or clamps in such a way that the accidental starting of the machine will not tend to break the fixture on account of these members striking the machine as they revolve.

(6) Lubrication of tools: On deep work when long holes are to be bored or when surfaces are to be machined which are not readily accessible, it may be necessary to provide a means of carrying the cutting lubricant to certain surfaces. In some instances a pipe can be carried through the spindle to discharge the lubricant in front of the cutting tools, depending on the centrifugal action to throw it out to all parts of the fixture. At other times openings in the fixture can be made to allow the lubricant to reach the various parts.

(7) Convenience of operation: As the turret lathe is a high production tool, attention should be paid to the convenience of setting and removing the work in order to make it as easy as possible for the operator. The clamps should be arranged so that they are convenient of access and easy to operate. A little attention paid to these points when designing a turret fixture will be appreciated by the operator and will be found to increase the production to a considerable extent. It is sometimes necessary to make sure that the work is properly positioned in the fixture while the clamps are being set up. On work that is difficult to locate, a device may be used in the turret of the machine so that it will assist in locating and will help to hold the piece in an approximately true position while fastening the clamps.

There are a number of other specific points in connection with the design of fixtures, but as these cannot be handled under the head of general notes they will be treated specifically as the occasion demands. A number of cases will be cited during the progress of these chapters and the important features will be mentioned in the description.

A number of important matters affecting the design of tools and fixtures for the turret lathe have been mentioned earlier in this chapter. The subject is a broad one and the different types of tools considered in connection with their operation on

various kinds of work make it necessary to deal with specific cases as they may be illustrated. In every machining operation we must consider first the work and the method of holding it; second, the tools used; third, the machine movements and operation. We shall take up first the method of holding work of various kinds because it is logically the first step in design.

Chucks and Collets.—When a piece of work is of regular form it is usually held in chuck jaws or by means of collets. In either case the work is gripped by means of jaws which are contracted or expanded by means of the chuck or collet mechanism. On automatic and hand screw machines production work from the bar is commonly held in collet jaws. If the work is a forging or

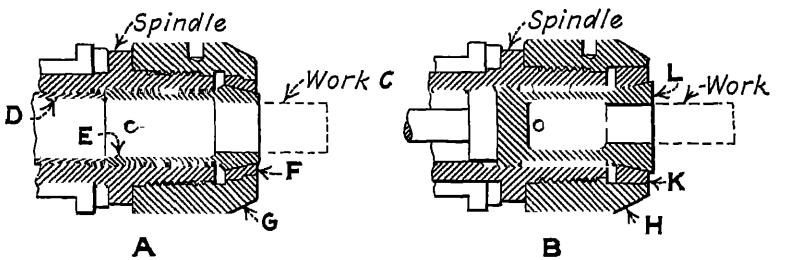


FIG. 7.—Push-out and draw-in types of collets.

casting or if it is "cut-off stock" it may be held by means of chuck jaws. For the purpose of discussion we need not consider in detail the many varieties of chucks and collets which are in use. It is however, necessary to understand something of the working of both devices in order that the design of special jaws may be made clear.

Strictly speaking there are two forms of collets, one of which operates with a "push-out" movement and the other with a "draw-in" motion. These two forms are illustrated in Fig. 7. The example at *A* shows the push-out type while that at *B* is the draw-in type. The work shown at *C* may be a bar of stock which extends entirely through the spindle or it may be a short piece, according to the conditions of manufacture. In operation, the sleeve *D* is moved forward by means of a lever at the head end of the machine, thus forcing the collet *E* forward into the taper bushing *F*, which is mounted in a nose-piece *G* on the end of the spindle. As the collet is moved forward it contracts and grips the work firmly.

In the example B the operation is just the reverse. It will be seen that the nose-piece H is furnished with a bushing K into which the collet L is drawn back, thus contracting it on the work. In each of the cases shown the collet is of one piece which has been split in several places to permit it to expand and contract as controlled by the taper at the end. Both of the collets shown in the preceding illustration have a certain amount of end movement which may possibly affect the holding of work which has been previously finished. In other words slight variations

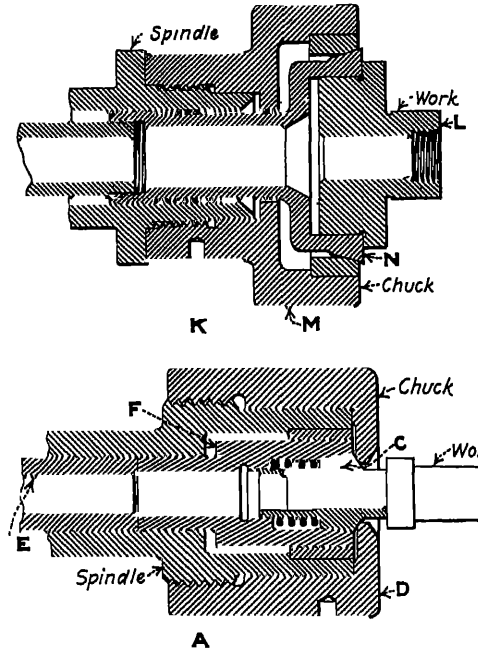


FIG. 8.—Collets without end-movement.

in the diameter which is being held will cause a variation in the position of the work with respect to the end of the spindle.

A type of collet which does not have any end movements is shown in Fig. 8 at A. In this type the work B is held by means of three loose jaws C which are provided with retainers in the chuck body so that they will not drop out. A nose-piece D fits the end of the spindle and keeps all of the parts in place. The collet is closed by means of a sleeve E which pushes forward a tapered member F, thus closing the jaws. The construction of

the chuck is such that there is no appreciable movement forward or backward when the device is operated. It is therefore possible to locate work accurately against the end of the collet so that it will always be held in a certain relation to the end of the spindle.

In the example *K* the work *L* is a casting of such size that it cannot normally be held in a collet. However, it is possible to grip work of this kind in a special oversized type such as that shown. This device is operated in the same manner as the draw-in type shown in Fig. 7. The nose-piece or chuck *M* is larger than the standard form and the collet *N* is split in several places so that it will contract and expand as controlled by the tapered portion.

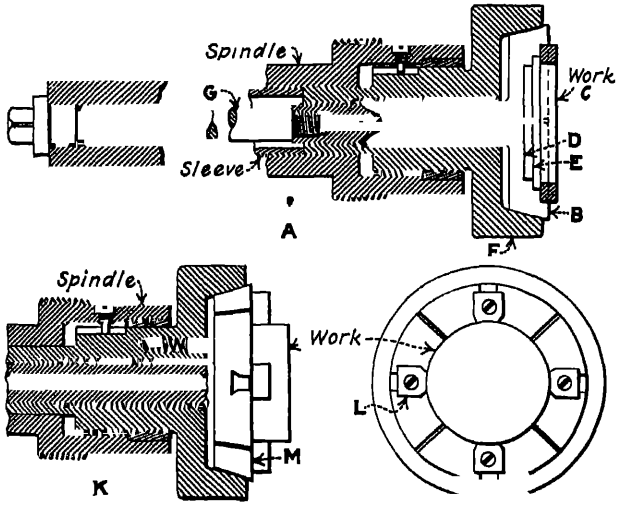


FIG. 9.—Step-chucks.

There are other forms of collets adapted to particular kinds of work but as these are more or less specialized they will not be illustrated here but will be taken up in detail later. It is possible to form out a set of collet jaws for a given piece of work and it may be profitable to do so when work is made in large quantities. As a general thing, however, pieces which are slightly irregular are more likely to be adapted to a two-jaw chuck in which the jaws are formed to fit the contour of the work.

Step Chucks.—In Fig. 9 is shown another application of the collet principle to work which is so large that it cannot be held in the regular form of collet. Devices of this kind are called "step chucks" because they are frequently "stepped out" to

various diameters so that several sizes of work can be held in the same chuck. Although used largely for second operation work where pieces have been partly finished, they are also useful in holding rough work, when castings or forgings do not vary greatly in diameter. Two types are shown in the illustration, one of which *A* has a soft spring collet *B* which is "stepped out" to hold the work *C*. It has also been bored out at *D* and *E* for two other sizes of collars. The collet *B* is split in several places so that it will expand and contract readily when it is controlled by the movement of the sliding closer *F*. This is operated by a lever at the end of the machine in the same manner as a collet of the ordinary type. The rod *G* extends through the spindle

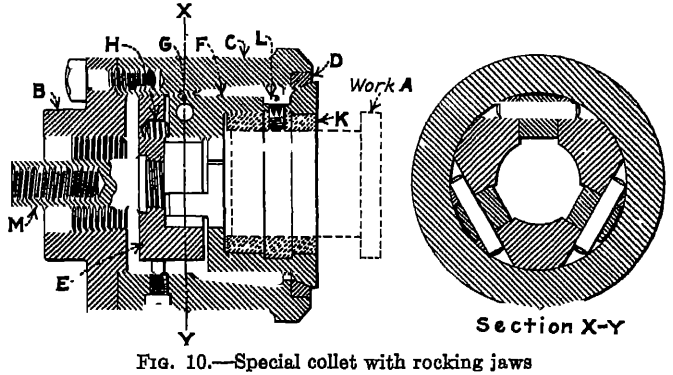


FIG. 10.—Special collet with rocking jaws

and holds the portion *B* in a fixed position endwise. Therefore chucks of this nature are very desirable for second operation work as it is possible to always locate the piece so that it is in a certain relation to the end of the spindle.

Another type of step chuck is shown at *K*. This type is somewhat more flexible than the one which has just been described because it is provided with loose adjustable jaws as indicated at *L*. These jaws are soft, so that they can be bored out to fit a given piece of work, and as they are easily replaced with others, the up-keep of the device is excellent. The general construction and operation are similar to the one shown at *A* but for some classes of work it is not as good as the former type. For example, if a piece of very thin work were to be held with considerable pressure it would undoubtedly be distorted due to not being properly supported. It is possible, however, to make up special jaws for a condition of this kind so that the jaws will

act as large segments of a circle and thus envelope the work so that it will not tend to distort, even if it were quite thin. If necessary, special jaws of this kind can be so made that they will form segments of nearly 90 deg., although when this is done it is advisable to provide them with extra setscrews to hold them securely on the face of the portion *M*. The tool designer is not usually called upon to design special jaws for step chucks, but the methods used are interesting and should be thoroughly understood so that special forms may be applied when necessary.

In Fig. 10 is shown a special form of collet designed for the work shown at *A*. This device is quite different from any of those previously shown, yet its functions are somewhat similar. A special nose-piece *B*, is screwed to the end of the spindle as indicated, and a chucking ring *C* is suitably mounted on the nose-piece. A hardened ring *D* is inserted as shown, this ring being bored out to a taper of 15 deg. The inside of the chuck is fitted with a holder *E* in which are three jaws *F* pivoted on pins at *G* and held open normally by means of stiff coil springs *H*. Special inserted jaws *K* are held in place in the movable members by means of screws shown at *L*. These jaws are bored out to suit the work that is to be held. The entire mechanism is operated by means of a rod which passes through the spindle and connects with the sleeve *M*, the latter being screwed into holder *E*. The chuck is operated by means of the collet mechanism usually provided on screw machines.

There is a slight objection to this type of holding device on account of the rocking action of the jaws. In holding finished work this would not be likely to cause trouble, but on rough work where considerable variation may be found, the holding might not be uniform unless a slight float were to be permitted at the pivot point *G*, so that the jaws could align themselves with the work and take care of normal inequalities or variations.

Inside Holding by Means of Collet Mechanism.—Work is occasionally found which requires holding by the inside and in many cases a two- or three-jaw chuck is used for the purpose. There are cases when another method may seem advisable if the work is small so that it cannot be easily adapted to a chuck. An example of this kind is shown in Fig. 11 in which the work *A* is a ring having an angular inside surface. In order to provide a rapid method of handling, the device shown was applied with good results. The spindle of the machine is fitted with a sleeve

B which is slotted in three places to receive the special rocking jaws *C*, which are three in number. A steel collar *D* is fastened to the outside of the sleeve *E* in such a way that it covers the slots and also provides for the thrust of the coil springs at *E*. The jaws *C* are pivoted on pins at *F* and they are tapered on the inside to conform to the angularity of the plug *G*. The operation is controlled by the collet mechanism in the usual manner, the tapered plug *G* forcing the jaws *C* outward so that they grip the inside of the work firmly.

An advantage of this type of holding device is that it permits facing the work on both sides *H* and *K* in the same setting, and

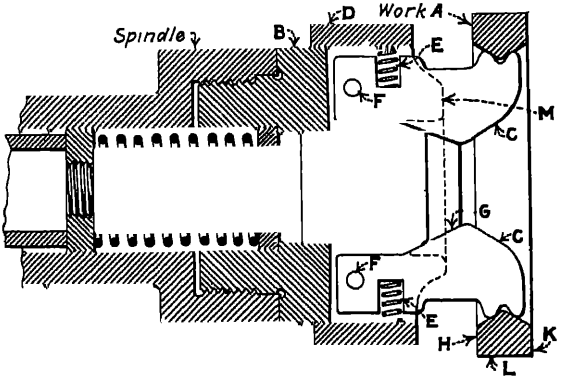


FIG. 11.—Special inside holding device.

permits the turning of the outside diameter *L*. It would be possible to extend the sleeve *B* somewhat further than the point *M* if the nature of the work would permit it and this might be an advantage in that it would give the jaws a better support. It depends upon the nature of the work and its general construction and the designer must be governed accordingly.

Two-, Three- and Four-Jaw Chucks.—Chucks having three jaws with a universal movement about the center are largely used in production. The fact that all three jaws operate simultaneously and with a uniform movement is an important item when work is to be centrally located. The two-jaw chuck is also a favorite in holding work of small size for production. This type of chuck is also commonly made so that the movement of the jaws is uniform about the center. A chuck having four jaws operating independently is not often used for production work,

although there are cases when it may be found necessary. Fig. 12 shows a diagram of the three varieties of chucks mentioned. The two-jaw chuck shown at *A* is usually so made that special jaws can be inserted in a dovetail slide as shown at *B* and *C*. These are often called "slip-jaws." This variety of chuck is operated by means of a right- and left-hand screw which sometimes passes through the center of the jaws and at other times is at one side. For any work which is long it is necessary to select

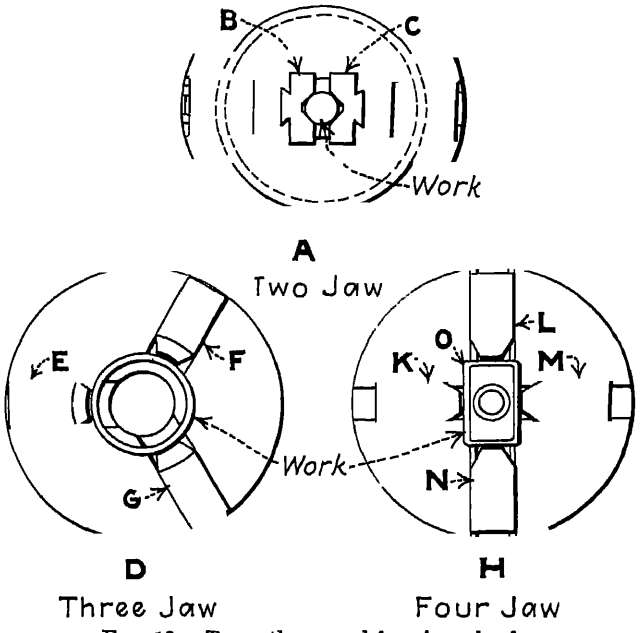


FIG. 12.—Two-, three- and four-jaw chucks.

a chuck having an operating screw at one side of the center, so that the work can extend back and not interfere with the screw. The majority of manufacturers who deal in these chucks can supply them either way. The three-jaw chuck shown at *D* is a prominent factor in production work, as the three jaws *E*, *F* and *G* are uniformly arranged about the center so that when in operation they exercise a centering action on the work. Different methods of controlling these jaws are used, but a common method employs the use of a scroll ring which engages with grooves cut on the under side of the jaws. As the scroll is

revolved the jaws are drawn in or out according to the direction of the movement.

The four-jaw chuck shown at *H* has its jaws arranged at 90 deg. from each other as at *K*, *L*, *M* and *N*. Each of these jaws is operated independently by means of a screw. In using a four-jaw chuck for production work it is common practice to allow two of the jaws to remain fixed so that they act somewhat as a "V." In the case shown we can consider that the jaws *L* and *M* are stationary and the work *O* is located in position and clamped by the action of the two jaws *K* and *N*. When a chuck of this kind is used for other than production work, it is necessary to adjust the jaws separately and "indicate" the work until it is found to be in a central position.

There are various methods of operating both two- and three-jaw chucks, although those mentioned are commonly used. The air-operated chuck is used very largely for rapid production and there are other types which are operated by means of cams. The particular method of operating the chuck, however, does not concern the tool designer to a great extent except as he may be required to select the chuck for a given operation on a piece of new work. It is advisable for him to become familiar with the methods of operating and the advantages of the various types in order that he may be better able to judge which particular type is most suited to any given piece of work.

In the design of special chuck jaws there are a number of important points to be considered. The nature of the work, its general shape, the material of which it is composed, the thickness of the casting, the position of any letters or figures on the outside of the casting, the parting line, the angularity of the work caused by the draft and possibly some other matters, all have a bearing on the method of holding. In addition to these points, the cutting which is to be done and the various surfaces which are to be machined must be taken into consideration. No matter whether the work is to be held in a two-, three- or four-jaw chuck or whether the casting or forging is regular or irregular, the following points must be carefully noted·

(1) Chucking; in placing the work in the chuck jaws, care must be taken to see that proper provision is made so that two men will not be required to set up the work, viz.: one man to operate the chuck jaws and the other to hold the work in position. If a condition should arise such that the casting could not readily

be placed in position and locked securely by one operator, it would be necessary to provide a special chucking device on the turret of the machine to hold the piece in its proper position while tightening the chuck jaws

(2) Location and support; in locating the work in the jaws, attention must be given not only to a proper method of holding but also to the points that are to be machined so that a locating surface will be selected such that subsequent operations will be considered in their relation to the accuracy required to the product. It is advisable to select points both for holding and locating which will not be likely to be affected by patternmakers' figures or letters, and the gripping points must be so arranged that they will not strike directly on any seams or "fins" on the casting. In supporting the work, the pressure of the cut and its direction as well as the possibilities of pulling the work out of the chuck under very heavy cutting must always be thought of. When wide surfaces are to be machined, proper support should be given to them so that they will not "buckle" under the stress of the cut. Other matters connected with the location and support of the work will be taken up subsequently as hereinafter illustrated.

(3) Driving; if the piece of work that is to be held is thin or fragile, it is well to provide a means of driving so as to take the strain away from the jaws and not make it necessary to set these up too tightly. It is often possible to use a projecting lug on a casting as a driver, letting it rest against the side of one of the jaws. In exceptional cases it is permissible to drill a driving hole in some part of the work, the hole being so placed that a pin in one of the jaws will act as a driver in the hole. The method of "serrating" the jaws is an important factor in driving the work, but the serration must be proportioned properly in order that the points will grip the work and yet not become dulled too easily.

(4) Distortion; no matter what kind of work is being held in chuck jaws (except, of course, solid stock), there is always a possibility of distorting the work by applying too much pressure on the jaws. Careful consideration should therefore be given to this matter when designing chuck jaws. In very heavy work there is not much danger, but when pieces are thin, the greatest care must be used. The matter of distortion will be discussed more fully in a subsequent chapter.

(5) Economy; the cost of the fixture does not necessarily govern its economy; it is possible that although it appears costly, the saving in setting up and removing the work is sufficient to counteract the extra cost of the fixture. Naturally, it makes a great difference whether a small or a large quantity of pieces are to be machined. In the latter case any saving in the time of setting up will result in a greater production and consequently less unit cost. For high production tools, provision should be made for replacing worn or broken parts with the least possible expense. All locating points and other parts subject to great wear should be so made that they can be readily replaced.

(6) Safety of the operator; in turret and engine lathe work, the holding fixture or chuck revolves and therefore the greatest care should be taken that there are no projecting points or parts which might catch on the operator's clothing and endanger his life. Setscrews which project are very bad and can generally be avoided by the use of the hollow type of screw. Clamps should be properly guarded and any other parts should receive the same careful consideration. In some cases on large work, it is necessary to build a special guard in order to make sure that there will be no danger to the operator.

CHAPTER II

DESIGN OF CHUCK JAWS

JAWS FOR TWO-JAW CHUCKS—PRINCIPLES INVOLVED IN CHUCKING—SERRATED JAWS—USE OF SUPPORTING SPIDER—TYPES OF SPECIAL JAWS—CHUCKING LONG WORK—USE OF LOCATING RINGS—SPECIAL FACE-PLATE FIXTURES—RING POT FIXTURES FOR RECTANGULAR WORK—HOLDING THIN CASTINGS

When jaws are to be designed for a two-jaw chuck it must be remembered that as a general thing these jaws are of the "slip"

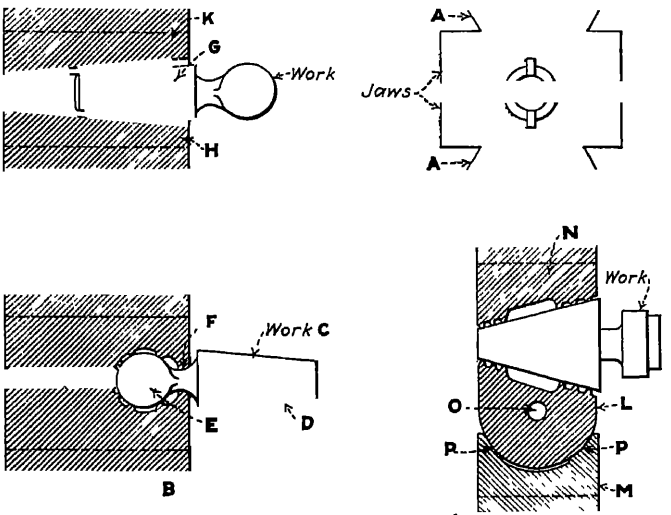


FIG. 13.—Jaws for two-jaw chucks.

variety. They are usually dovetailed, as shown in Fig. 13 at *A*. This dovetailed portion fits the solid jaw in the chuck and must be made in accordance with the standard of the chuck in which they are to be used. One of the common forms of chuck jaws is the V-jaw used for holding round pieces. It is possible to buy jaws of this kind from the manufacturer or they can be made

up in sizes to suit the conditions. Two-jaw chucks are usually applied to work of comparatively small size and frequently the jaws are formed to fit a forging or a casting of a certain particular shape. The jaw in this case then acts as a "nest" into which the piece is dropped and its location in the jaw is determined by the shape of the "nest." In the example *B* the work *C* is a cock which is to be machined on the tapered portion *D*. The jaws therefore are made so that they will grip the ball end as shown at *E*, and at the same time locate the piece centrally by means of the two projecting points at *F*. It is customary in work of this kind to furnish samples of the parts to the toolmaker with a sketch showing the method of location but without giving many dimensions. Instructions are then given to fit the jaws to the model.

In holding tapered work, if the piece is smooth such as that indicated at *G*, it may be difficult to hold it by making two tapered jaws as shown at *H* and *K*. It depends a great deal on what the taper is, but if it is over 15 deg. included angle, jaws of this kind should not be made, as the pressure of the cut on the work is likely to pull it out of the jaws. This is particularly noticeable if the direction of the cutting is such that it presses outward away from the jaws even in the slightest degree. It is sometimes possible to hold work of this kind by notching the jaws so that they will bite into the work, but even this is rather unreliable as the taper of the piece may vary somewhat so that it does not make good contact all along the taper. In order to be sure that no trouble will be caused by an improper method of holding, it is much better to make one of the jaws with a "rocker" like that shown at *L*. This jaw is mounted in a "slip" jaw *M* which is held in the regular way in the standard jaw. The opposite jaw *N* is tapered according to the angularity of the work. When the piece is placed in position the swivel jaw rocks in its seat and adapts itself to variations in the taper. In the design of a rocking jaw the pin *O* should only be considered as a retainer and the thrust of the jaw should be taken on the solid portion *P*.

Two-Jaw Method for Inside Holding.—Fig. 14 shows at *A* a counterbalanced flywheel which is to be finished as marked, in one operation. The flywheel is cast with heavy portions at *B* and therefore it cannot be held in a three-jaw chuck. Two special jaws *C* and *D* are fitted to a standard two-jaw chuck body, one jaw *C* being fixed while the other *D* is provided with a

rocker or swivel jaw E. This rocking jaw is relieved at the center so that it makes a contact automatically at F and G on the inside surface of the flywheel. The portion H is cut on a slight angle in order to assist in keeping the jaw in position under the pressure of the gripping action Attention is called to the manner in which both jaws touch the work and also the way in

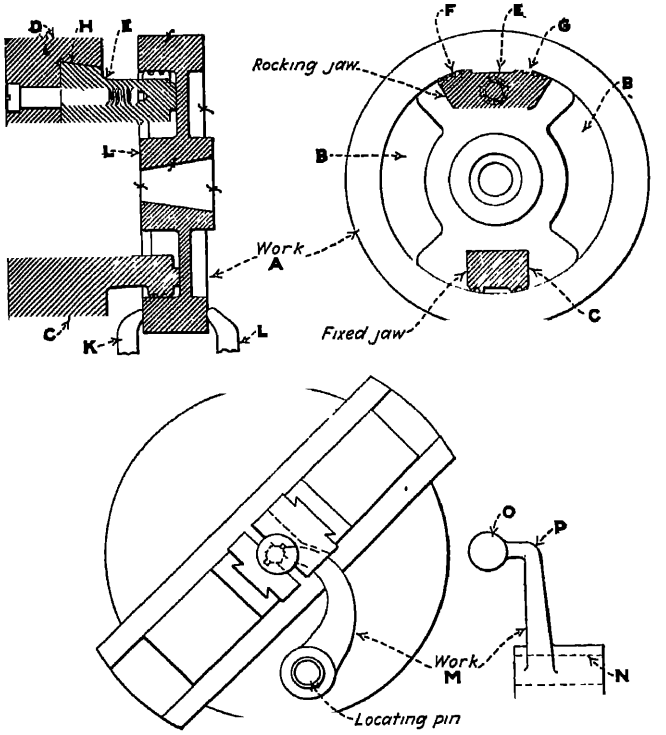


FIG. 14.—Two-jaw chucks with special jaws

which they are relieved to permit the facing tool K to operate without interference. Incidentally, tools K and L are used on the cross-slide of the lathe. The other operations are performed by turret tools with the exception of the surfacing of the hub L which is done by a back-facing attachment through the spindle of the machine. The tooling for work of this kind will be taken up in a subsequent chapter.

The work M is an angular ball-end lever which has been previously machined at N. A two-jaw chuck is used for holding

this piece while finishing the ball *O*. The face of the chuck is provided with a locating pin which is a loose fit in the hole *N*. The jaws are of the "slip" variety and are formed to grip the neck of the work at *P*. A small amount of "float" allows the work to adjust itself in the jaws so that the ball portion can be held without difficulty. This example is an instance of a set of jaws which is formed from the model. The drawing would be made with some of the dimensions left off and instructions given on the drawing to "fit to model."

Swivel Jaw Application for Two-Jaw Chuck.—An example is shown in Fig. 15 of the application of a combination swivel and

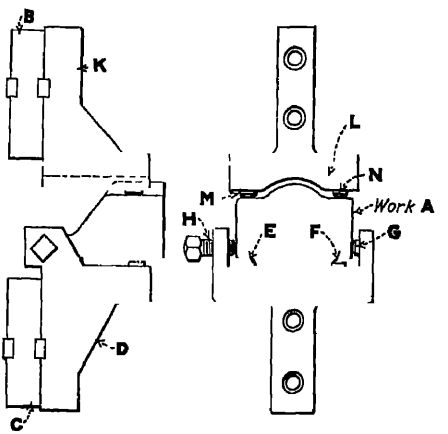


FIG. 15.—Special two-jaw method of chucking.

special jaw to a two-jaw chuck. The work *A* is roughly rectangular in shape at one end but irregular on the other end. The jaws *B* and *C* are standard chuck jaws on a special form of two-jaw chuck. On one of these jaws a member *D* is mounted. This is provided with hardened points at *E*, *F* and *G* so that the work rests against the points. The setscrew *H* holds it in place. The other jaw *K* is provided with a swiveling member *L*, having two points at *M* and *N*. These two points adapt themselves to the variations in the casting, thus holding it securely. This particular piece of work is a little out of the ordinary and the method of holding allows the work to be centered and held without distortion.

Principles Involved in Chucking.—Errors are often made in designing chuck jaws by attempting to grip the work on too

many points without any provision being made for equalization. In our discussion of drill jigs and milling fixtures we brought out the matter of the three point support quite carefully and it should be remembered that the same principle holds good in the design of chuck jaws. Unless care is taken in the design, there is a possibility of an error being made which will cause a piece of work to be held improperly. Let us consider the diagram shown in Fig. 16 in connection with the holding of a cylindrical casting K in a three-jaw chuck. The work can be held without difficulty

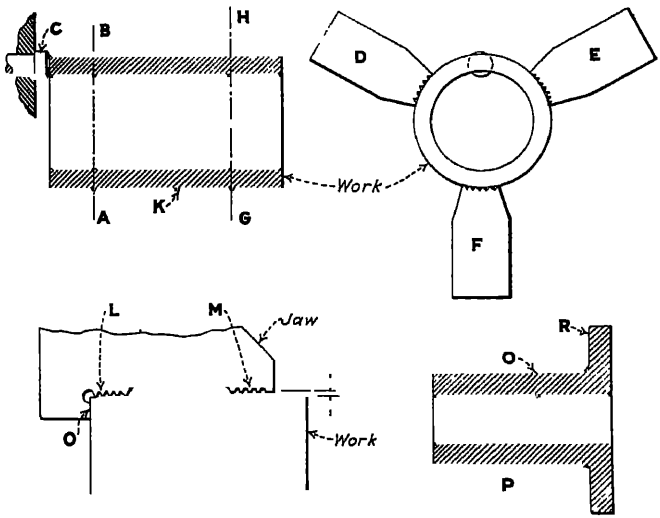


FIG 16.—Principles involved in chucking.

by the three jaws D, E and F in the plane AB and it can also rest against one point as shown at C. Any other portions of the work which are to be gripped by the jaws must be taken care of by means of adjustable points or screws. If we wish to obtain additional support in the plane HG by extending the jaws so as to grip the work in this plane, the result would probably be something like that shown at L and M. In other words, the jaws would strike at L and not at M, or it might be just the reverse of this, according to the shape of the rough casting. It might even be that some jaws would strike at M and others at L, the result of which would be that when cutting tools were put into the work the piece would change its position or vibrate to a con-

siderable extent. It is not necessarily objectionable to design a set of jaws having supports of equal height at *O*, because only one of these points will strike and the others may simply help in chucking the work in the first place to obtain the correct end location. In the example *P* therefore it would be possible to make a set of jaws so that they would bear at *Q* and *R* and although all the jaws would not strike at *R*, one of them would, which would be sufficient to obtain the location.

Many kinds of work can be held in standard jaws either by the outside or inside. Fig. 17 shows an example *A* in which the work *B* is being held by the outside in the set of standard jaws *C*. The example *D* shows a piece of work *E* being held by

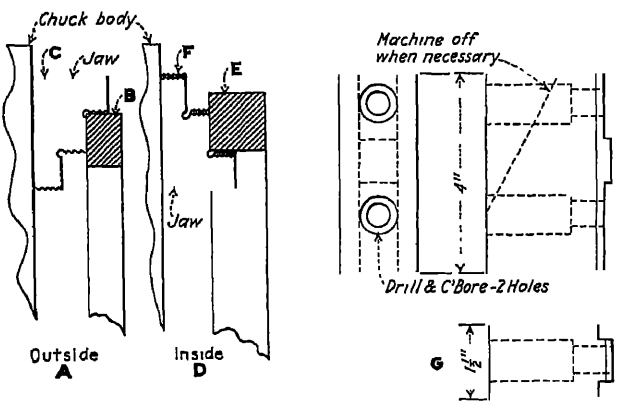


FIG 17.—Standard chuck jaws.

the inside in a set of standard inside holding jaws *F*. Work of this kind seldom requires special jaws unless it is so thin that a facing operation cannot be done without running into the jaws, in which case special jaws might be made similar to those shown.

In production work it is advisable to standardize jaws as far as possible and avoid the changing of the entire jaw in any chuck. By means of standardization, jaw blanks can be made up like those shown at *G* and they can even be fitted to a master plate so that the only work necessary in making up special jaws will be the cutting of the jaw blank into the desired shape. Of course there are cases where special blanks are required, but in most cases certain standardized heights can be utilized if they are made up as indicated.

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Fig. 18 is given in order to illustrate several important points connection with the chucking of cylindrical work. The piece is to be machined at *B*, *C*, *D* and *E* and it would normally be d for this purpose in a three-jaw chuck by the outside of the b. A casting of this sort is likely to come from the foundry in out the shape indicated by the dotted lines at *F* rather than as own on the blueprint. In other words the patternmaker will turally allow some draft in order that the piece may be easily noved from the sand. If then an attempt is made to hold the rk in a set of chuck jaws like that shown at *G* the result will be contact only in the plane *HK* so that there will be very little

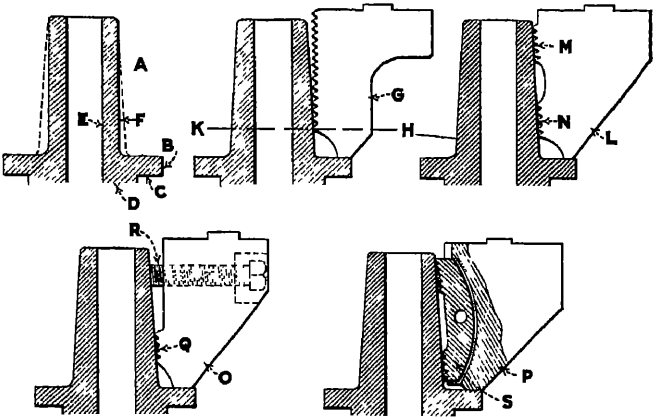


FIG 18.—Several methods of chucking a flange

ipping action to the jaws and the piece is likely to be considerly disturbed while the cutting action is going on.

In order to avoid such a condition, it is common practice make up the jaws to correspond with the taper on the casting shown at *L*. We wish to say a word against this practice cause it is very seldom satisfactory on account of variations in e casting. Sometimes it will be found that the work will be ipped by the portion *M* which allows the front end of the castg to "wobble." At other times the portion *N* may hold the ork and then there is not sufficient gripping action to hold e piece firmly. Trouble is usually caused by variations in the sting which may be caused by several different patterns being ed or by the work being cast in several places. It is much tter to use a set of jaws like those shown at *O* or *P*.

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In the case of the jaws at O, the work is gripped and centered at Q and it receives additional support from the screws R. The other method shown at P involves the use of two jaws with rockers as shown at S and one jaw formed to the approximate taper of the work. This latter is undoubtedly the best method of holding a piece of this kind although the method shown at O is considerably cheaper and will answer the purpose in the majority of cases. It is open to the objection that the operator may fail to tighten the screws sufficiently, or he may tighten them too much, thus distorting the piece and making it untrue.

Method of Serrating Jaws.—If a design for chuck jaws is made

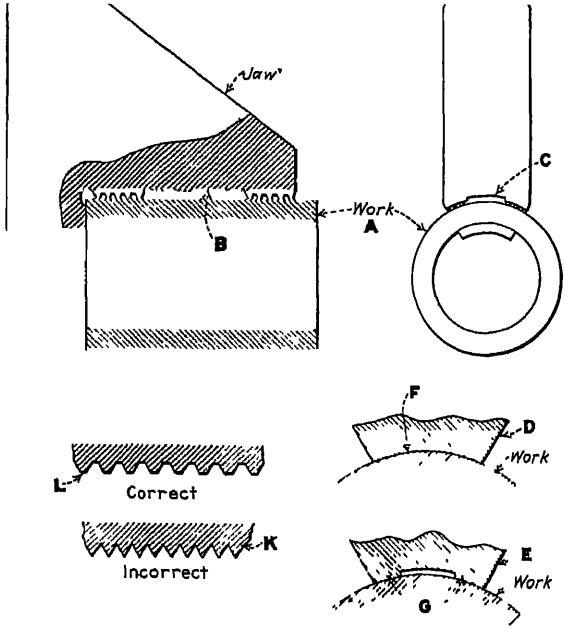


FIG. 19.—Method of serrating jaws.

and sent to the factory or toolroom to be manufactured without specific instructions, the result is likely to be disastrous. It is seldom that a tool designer gives sufficient attention to this matter in making his drawing. It is a very good idea to examine some of the standard jaws that are put out by the chuck manufacturers and note the method used in serrating them. Fig. 19 shows the correct and incorrect methods of serrating jaws. In the case of the work A, which is to be held, the piece is cylindrical

in shape and somewhat long so that in order to obtain a good bearing on both ends it would be advisable to relieve the jaws at the point *B*. It is also advisable to relieve the jaw in the other direction as shown at *C* as this will give a better gripping action on the work than if the serrations are carried the full width of the jaw. The conditions obtained are shown at *D* and *E* in an enlarged view. If made as at *D* it is quite possible that a contact on the surface of the work will only be made at *F*, while if relieved as at *E* it is certain that a good gripping action will be obtained at both points *G*.

In the cutting of the serrations in the jaw, care should be taken never to bring these up to a sharp point as shown at *K*. If jaws are made in this way the points will soon become dull or broken and the gripping action will be injured. If made with a slight "land" as shown at *L* the surface will continue to be hard and there will be less chance of breakage. A "land" of $\frac{1}{32}$ in. is sufficient and the angle of the cut can be any where from 15 to 30 deg. depending on conditions. It is customary to make lands wider where they grip the work as at *G* than they are in the other direction. They are often made $\frac{1}{16}$ in. in this direction. Chuck jaws are usually made from machinery steel and pack hardened.

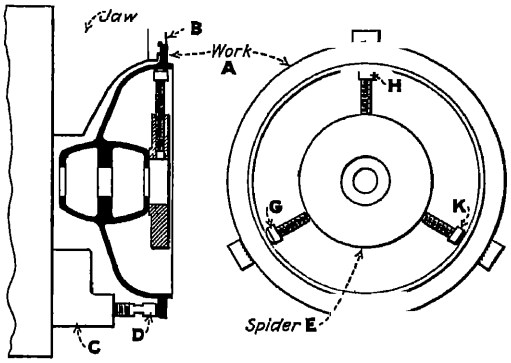


FIG. 20.—Supporting spider for chucking.

Supporting Spider for Chucking.—When work is rather large and fragile and must be held by the outside diameter there is a tendency to distort it unless some provision is made against it. Fig. 20 shows an example of this sort in which the work *A* is held in special jaws *B* by the outside of the flange. This work would be very much inclined to become distorted both in the chucking

and also in the machining unless something were done to prevent it. There are three supplementary blocks *C* placed midway between the chuck jaws. Screw jacks *D* are set in each of the supporting blocks so that they can be adjusted to support the flange between the jaws. In addition to this, a loose spider *E* having three setscrews at *G*, *H* and *K* is utilized. These setscrews are set out until they support the work opposite to each one of the three jaws. A hole is provided in the middle of the spider so that boring bars and other tools can be used to machine the work. The use of a method of this kind makes it possible to machine this piece without either vibration or distortion.

Two Types of Special Jaws.—Fig. 21 shows a piece of work at *A*

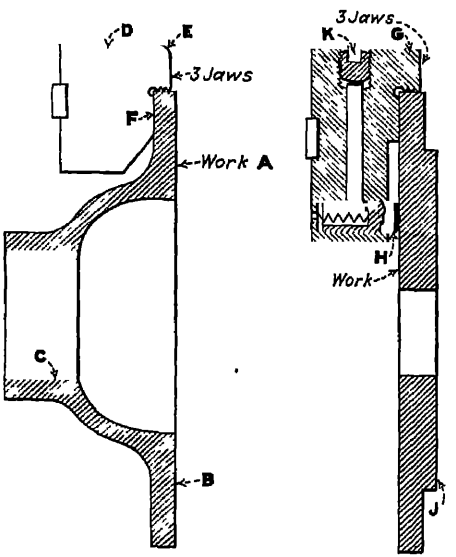


FIG 21.—Two types of special jaws.

which is to be machined at *B* and *C*. A set of special jaws suited to it are shown at *D*. The jaws are so proportioned that the face *E* lies back of the machined surface *B* and the work rests against the jaw at *F*. This method of support would be sufficient for a piece of work like that shown, but if the work were larger and was to be machined on a broader surface like that shown at *J*, additional support might be necessary. To provide for this a set of jaws could be made like that at *G*. These would grip the work and locate it in much the same manner as those

previously mentioned, but an additional support is provided in each jaw at *H*. This is a spring jack which bears against the surface of the work and which is locked in place by the pin and hollow setscrew at *K*. For work which is very thin and which requires considerable machining over a broad surface, a method of this kind would be found satisfactory.

In a previous illustration several methods were shown for holding long, cylindrical work, but these were comparatively small pieces. The casting shown at *A* in Fig. 22 is of good size and quite long so that it needs additional support at the outer end. It would be possible to design a set of chuck jaws to hold

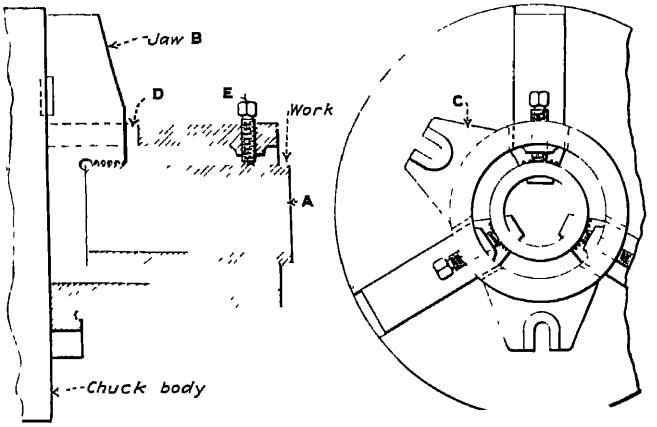


FIG. 22 —Chucking a piece of long work

it without any additional means of support, using one of the principles shown in the previous illustration. A simpler method and one which is less expensive is given, however, as it is more suited to the particular piece we have illustrated. The method of centering the work is by means of jaws *B* which not only provide an end location but at the same time center it accurately In order to give support to the outer portion of the casting a ring pot *C* is fastened to the face of the chuck This pot is cut out in three places at *D* in order to allow the chuck jaws to operate Considerable allowance should be made around the jaws in order to prevent trouble which might be caused by chips and dirt. By coring the holes in the casting no machining is necessary except the facing of the bottom of the pot and the drilling and tapping for the set-screws at *E*. These screws are used to sup-

port the work and are set up by hand. When each piece is placed in the jaws care must be taken not to exert too much pressure as otherwise the casting might be distorted. It would be possible to use spring jacks in place of set-screws and there would be some advantages in this method as there is less likelihood of distortion. This is a cheap arrangement, involving very little trouble and giving satisfactory results.

Chucking with a Locating Ring.—The example shown in Fig

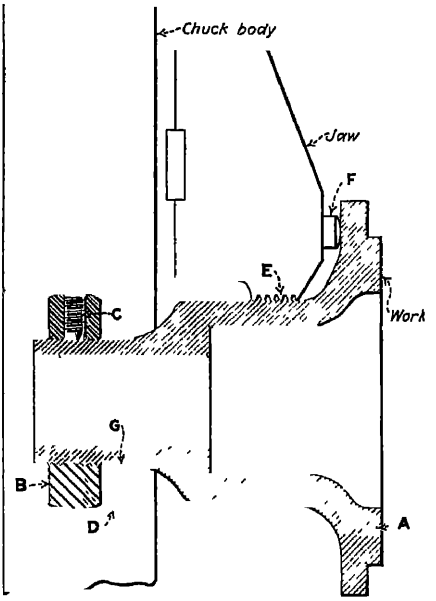


FIG. 23.—Chucking with a locating ring.

23 is a little out of the ordinary as it involves the use of a chucking ring *B* which is placed on the casting *A* and which helps to support and center the long hub. Several chucking rings should be provided as they are put on the casting before it is placed in the chuck. A setscrew *C* holds it firmly in place so that the end does not "wobble." The outside of the ring is made in spherical form so that it fits the hole in the chuck at *D*. The jaws used in this case are arranged so that they grip the work at the point *E* and the end location is obtained through the hardened stud *F*. A method of this kind can be used to advantage when the work is long and it is not desirable to have it extend too far out from the face of the chuck. The portion *G* of the casting is slightly

apered so that the ring fits it snugly and it is often unnecessary o tighten the setscrew. Theoretically the jaw at E should be lmost a knife edge but in actual practice it can be made about s shown without experiencing any difficulty.

The pot casting shown at A in Fig. 24 is to be machined at B nd C in such a way that the outer wall is concentric with the nside. It is therefore necessary to devise a means of holding vhich will locate the work from the inside cored surface. The chuck is equipped with entirely special jaws, one of which D bears at E and F on the inside of the casting. A reference to the end view will show that jaw D is quite wide and that it is relieved

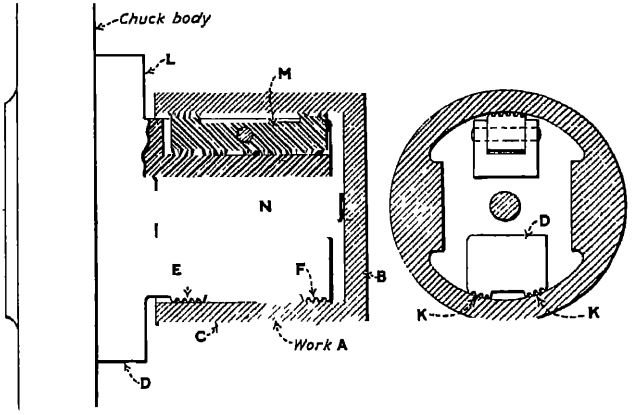


FIG. 24.—Two-jaw chuck with equalizing jaw.

n the center so that it bears at two points K on the inside surface of the casting. The other jaw L has a swivel member M which equalizes any variations which there may be in the inner cored surface, thus permitting the chuck to grip the work firmly and with a uniform pressure. The rod N is set into the body of the chuck so that it will act as an end stop for the casting. When jaws of this kind are to be made it is quite necessary to make them very substantial on account of the amount of overhang from the chuck. Unless they can be made very stable it is not advisable to use them but rather to devise some other method of holding, in order to obtain the desired results.

In Fig. 25 is shown a piece of work A which cannot readily be held in chuck jaws. It appeared advisable therefore to make up a special faceplate for the purpose. The faceplate B is

fastened to an adapter *C* which screws on to the end of the spindle. In the center of the faceplate is a spring bushing *D* which has a tapered end *E*. This end acts as a locater in the casting and centers it on the faceplate. The flange *F* rests on three hardened points *D* equally spaced in the body of the fixture. These points are so arranged that they can easily be replaced when worn or broken. In setting up the work a plug can be placed in the turret of the machine and carried forward so as to hold the work in place while the clamps are being tightened. These clamps are three in number as shown at *G* and they are slotted so that they can easily be removed from the work

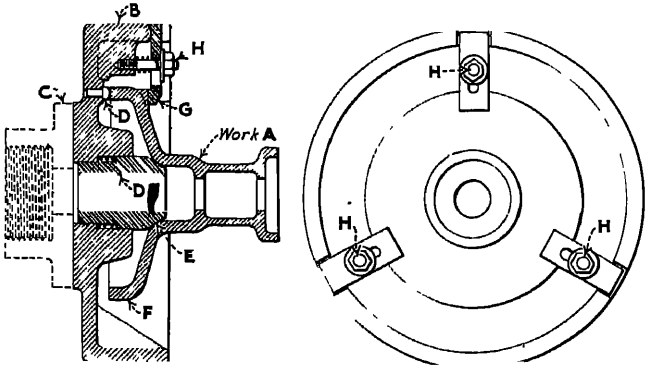


FIG 25.—Special faceplate fixture with locating plunger.

They are set up by means of nuts at *H*. Attention is called to the method in which the outside of the faceplate is carried up in the form of a ring in order to form a continuous surface so that the operator will not be endangered by projecting clamps. If desired, it would be possible to carry the bolts which operate the clamps through to the back of the fixture and tighten them from the rear instead of from in front. The convenience of the operator must always be considered when deciding on a point of this kind but in the particular case mentioned it would probably be fully as convenient to operate the clamps from the back as from the front and the cost would be little different from the method shown.

Chucking a Long Sleeve.—When work is very long and extends a great distance out from the spindle, it is sometimes necessary to provide an additional support other than that which can be obtained from the chuck or faceplate itself. It is always objec-

tionable to make any fixture with too great an overhang from the spindle as this is likely to cause vibration and imperfect work.

Fig. 26 shows an example of this kind in the work *A* which is a long cast-iron sleeve held and centered at one end by the chuck jaws *B*. A casting *C* is bolted to the face of the chuck as shown and the outer end of this casting is fitted to a cylindrical sleeve *D* and bolted thereto. At the outer end of this sleeve are three setscrews *E* which are used to center the work and hold it in position. A special steadyrest *F* is mounted on the ways of the turret lathe in such a way that it supports the sleeve *D* which is a running fit in the large bearing at *G*.

An arrangement of this kind permits a piece of long work to be held firmly even though it extends a long distance out from

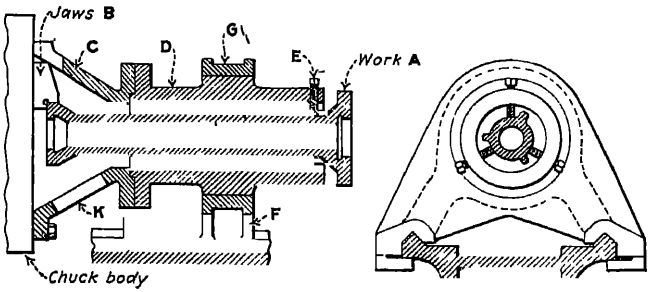


FIG. 26.—Chucking a long sleeve.

the end of the spindle. It is therefore possible to hold it securely and without any chance of vibration while the cutting tools are in action. The casting *C* is cored out so that the three jaws *B* can be readily moved without interference. Cored openings are also provided in the walls as shown at *K*, in order to permit chips and dirt to fall out. In making up a steady rest of this kind provision should always be made for oiling the bearing, either by means of a large glass oil cup or some other approved method.

Holding Thin Work.—The problem of holding thin work requires care and thought in its solution. The matter of distortion is of great importance and unless a proper method of holding is determined upon, the work will be untrue when finished. In addition to the possibility of distortion there is always a likelihood of extreme vibration on account of the thin and unsupported walls of the casting. Therefore the cutting tools that are used must be correctly designed in order to counteract this tendency as far as

possible. More will be said about this matter under the head of "cutting tools." Fig. 27 shows several methods of holding a thin ring pot *A*. This casting is of a type commonly used in making piston rings. Both the inside and outside of the casting are finished and it is then cut up into narrow rings of a predetermined width.

If the work here considered is held in jaws like those shown at *B*, the casting will undoubtedly be distorted from its original shape as shown at *C*, because it would not be possible to hold the

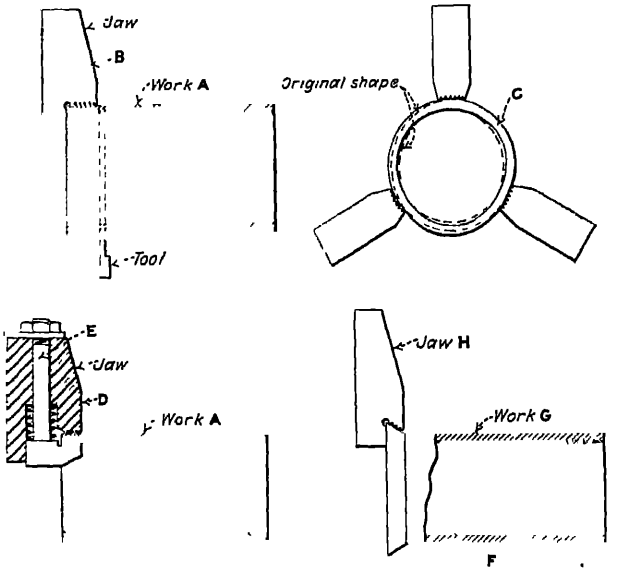


FIG. 27.—Several methods of holding a thin ring pot.

work firmly without exerting considerable pressure on the jaws. It is possible to avoid this difficulty by making up a set of special jaws like those shown at *D*. The outside of this jaw can be set up lightly on the ring part with just sufficient force to prevent it from turning freely by hand, and after this is done the hook bolt *E* can be tightened so as to make a firm metal-to-metal contact. There is an added advantage to this method of holding, in that it tends to "kill" the vibration in the metal and thus prevent "chatter." A device of this kind can be used for many kinds of thin work whether it is regular or irregular.

The method shown at *F* is most commonly used for the manufacture of piston rings. A special form of pot casting is

made up like that shown at *G*. One end is provided with an angular ring of sufficient thickness to withstand the crushing action of the chuck jaws *H*. The angularity of the ring keeps it from pulling out of the jaw and at the same time tends to hold it back strongly against the seat of the jaw. Naturally there is considerable waste when this type of casting is used, but this is offset by the convenience of operation and the good results obtained.

Two-Jaw Chuck Used for Rectangular Work.—The work *A* shown in Fig. 28 is a casting of such shape that it may be held

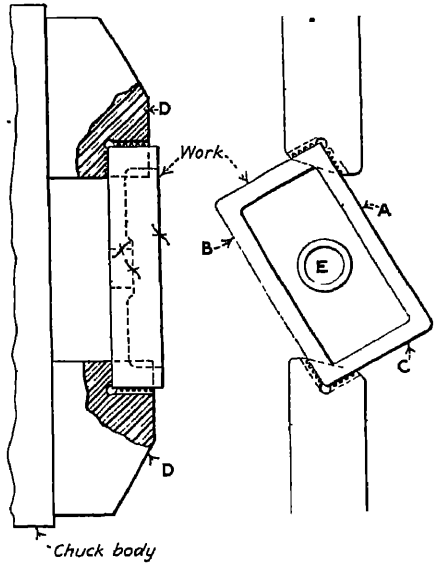


FIG. 28.—Two-jaw chuck holding rectangular work.

in a fixture or by means of chuck jaws. The work which is to be done is shown by the marks *f*. There is very little danger in using this method of holding if the casting is small; but if of large size it would probably be necessary to provide extra supports under the corners *B* and *C*. These might be made in the form of spring jacks and attached to the face of the chuck if desired. The jaws *D* in the case shown are cut out in V-form so that they receive the corners of the casting and at the same time center it so that the hub *E* is in proper alignment with the center of the spindle. The method of chucking shown here holds

the work very firmly but it is open to the objection mentioned when the work is large.

Holding Fixture for an Aluminum Casting.—In Fig. 29 is shown an aluminum casting *A* of somewhat similar form to that previously described, but the method of holding is decidedly different as the piece is considerably larger in size. Furthermore it must be made accurately to size and the surface *B* and the relieved proportion *C* must be machined very carefully. The fixture body *D* is bored out and threaded at *E* to fit the end of the spindle but it can also be made in such a way that it can be

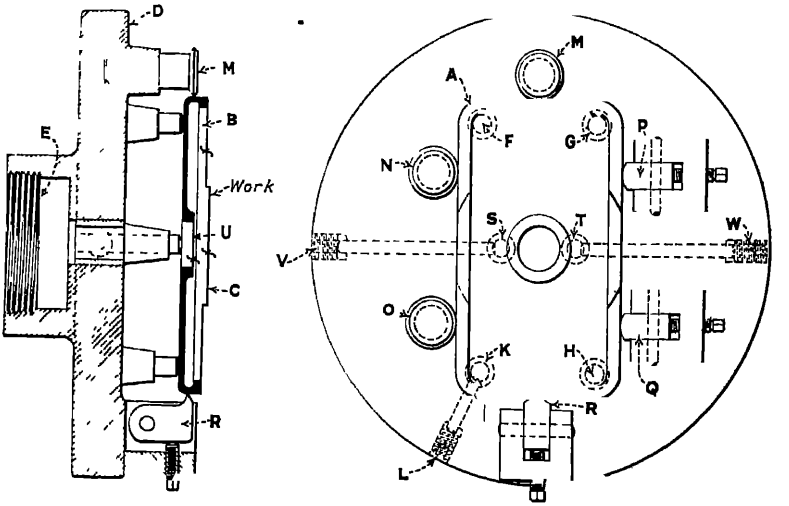


FIG 29.—Holding fixture for an aluminum casting.

attached to an adapter if this seems advisable. The work is located on three fixed points, *F*, *G* and *H* in the body of the fixture. A fourth point *K* is adjustable and can be made in the form of a spring plunger which is locked by the hollow setscrew and plug at *L*. There are three round knife edges at *M*, *N* and *O* against which the work is located by means of three swinging knife-edged clamps, *P*, *Q* and *R*, thus locating the work and at the same time preventing it from pulling out of the fixture. Two supporting jacks at *S* and *T* take the thrust of the cut when facing the boss *U*. These spring jacks are respectively located by the setscrews and plugs at *V* and *W*. This design of fixture will be found useful for work on which clamps cannot be applied

in the usual manner. The design is clean and simple and there is no tendency to distort the work unless too much pressure is applied to the clamps P, Q and R. The action of these swinging members has been previously described in Vol. I "Jigs and Fixtures" under "Drill Jig Design"

Holding Fixture for Fragile Aluminum Casting.—In Fig. 30 is shown at A an extremely difficult piece of work to hold and machine without considerable distortion. The fixture shown in the illustration gave excellent results in use although it appears somewhat complicated in design. The casting A is of thin alumi-

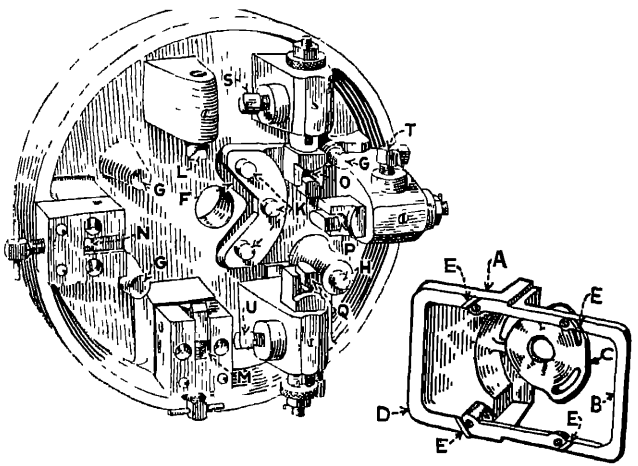


FIG. 30.—Holding fixture for a fragile aluminum casting

num and the portion B is approximately $\frac{3}{8}$ in. thick and entirely unsupported. The portion C is only $\frac{1}{8}$ in. thick and is machined all over the face shown. The entire face of the flange D is machined and the tongues E are also cut to an accurate diameter in the same operation. It will be understood from the foregoing that it is necessary to hold this work in such a way that it will not be distorted either by the clamping or during the process of machining. The work is set up and located in the "V" F on the body of the fixture and it rests on three fixed points G, and a spring plunger H. The portion E is supported by three spring plungers K. A single knife edged point L acts as a stop against one side of the work. It is clamped in this position by means of the swinging knife edge M and it is thrown over in the V-block F by another knife edge clamp N. The flange B rests between

the jaws of the floating hook bolts at *O*, *P* and *Q*. The floating clamps are so arranged that they can be tightened so that they hold the work firmly and yet do not distort it. After they have been tightened the setscrews at *S*, *T* and *U* hold each hook bolt in position.

CHAPTER III

SECOND OPERATION WORK

COLLETS, STEP CHUCKS, CHUCK JAWS AND ADAPTERS—CONSTRUCTION OF FIXTURES—SOFT JAWS FOR CHUCKS—USE OF STANDARD FACE-PLATE AS A FIXTURE—ADJUSTABLE FIXTURES—CHUCKING ECCENTRIC WORK

We have discussed in a previous chapter a number of methods of holding rough work on chucks and fixtures for turret lathe operations. It frequently happens that several operations are necessary on a turret lathe, or it may be that work has been previously machined on some other type of machine tool prior to the turret lathe operation. Under these circumstances, the location of the work for the turret lathe operation must be determined from some of the previously finished surfaces or holes. This chapter will take up a number of methods of holding work for a second operation locating from some previously finished surface.

There are several conditions which may affect work-holding devices of this kind. The piece may have been machined in circular form, either on the outside or the inside; it may have been drilled and reamed on a drill press; or it may have been milled, or otherwise machined on some other type of machine tool. For the turret lathe operation it is necessary to locate from some of these finished portions in order that finished dimensions may be held accurately to size.

Collets, Step Chucks and Chuck Jaws.—We have previously devoted some space to a description of collets, step chucks and chuck jaws, and much of the matter mentioned in connection with these devices can be applied to second-operation work. It is important, however, to observe that collets which are used for work which has been previously machined, are commonly not checked or grooved, but are left smooth and ground out accurately to the size of the work which they are to hold. Care must be taken not to mark the work by using jaws or other holding devices which will tend to rough up the finished surfaces.

The matter of provision for chips and dirt is particularly important in connection with fixtures used for second-operation

work. The greatest care should be taken to make all locating surfaces in such a way that they can be easily cleaned, so that the required accuracy will be obtained. Distortion caused by improper clamping, counterbalancing of the fixture in order to make it run without vibration, and projecting clamps or lugs should all be given due consideration; but, as these points have all been mentioned previously, it is unnecessary to go into detail regarding them, except in specific cases which will be hereinafter mentioned.

Application of Adapters.—In making up a fixture for use on a turret or engine lathe, it is advisable to avoid, as far as possible, fitting the fixture to the spindle. Spindles are threaded and

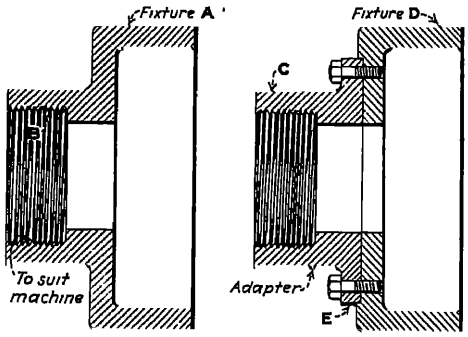


FIG. 31.—Advantage of using adapters.

turned, and any fixture which is to be applied to them must be very carefully bored out and threaded in order to obtain accurate work. If a number of fixtures are to be made up, this extra fitting to the spindle is costly and should be avoided by using some form of adapter of standard pattern, to which the fixture itself can be attached. Fig. 31 shows a diagram of a simple fixture *A*, which is fitted directly to the spindle at *B*. In making up a fixture of this kind, its cost is increased considerably on account of the fitting operation. Furthermore, if any part of it should be broken or injured, it would be necessary to replace the whole fixture and again fit it to the spindle. By the use of an adapter, such as that shown at *C*, the fixture *D* can be located on it at *E* by simply boring out the fixture to fit the flange. It can then be bolted in place with the assurance that it will run true with the spindle.

Another advantage of using an adapter for fixture work is that adjustments can be made in the fastening of the fixture to the adapter, so that it can be trued up if it becomes untrue after a long period of service. When a fixture is made as a unit to screw onto the spindle, it is difficult to make any adjustments after it has once been constructed. If it becomes inaccurate from use it will very likely remain that way, on account of the difficulty of making any changes which will bring it back into shape again. Several forms of adapters were shown in the first article on turret lathe work.

Any factory which uses fixtures of this nature to any extent should consider very carefully the standardization of adapters for the various machines to which fixtures are to be applied. On small-sized fixtures it may be found more convenient to use a center plug in the adapter, or a center hole into which a plug in the fixture can be set, rather than to use a flange such as the one shown. In standardizing a proposition like this, the designer should make drawings of the spindles of the various machines used, and try to make the adapters so that they will be generally uniform and without too many sizes of flanges to which fixtures are to be fitted. If flanges are made in only two or three standard sizes, it will be found possible to transfer a fixture from one machine to another when this seems desirable. In the case of a machine breakdown, or in transfering a machine from one department to another, an arrangement of this kind will often be found a great advantage.

Construction of Fixtures.—In considering the general features of construction of fixtures for turret and engine lathes, attention should be called to a few points of importance. Most fixtures are made of cast iron, although aluminum and steel are used occasionally. The necessity for keeping fixtures of this kind as light as possible, and at the same time attaining the necessary stability and rigidity, must be emphasized. Excessive overhang on the spindle is likely to cause vibration when the cutting tools are applied to the work, although the fixture may run true before the tools are applied. If it becomes necessary to make a very long fixture, or one which extends a considerable distance beyond the spindle end, suitable provision should be made to support it in some way or other, and thus take the strain off the spindle. This point was brought out in the last chapter with an illustration of a condition similar to that mentioned.

In the making up of fixtures, it is usually better to build up angular surfaces on the fixture rather than to attempt to make a casting with suitable projections on it. An important point is shown in Fig. 32 at *A*, in which an angular pad *B* is made up as a part of the fixture *C*. If this angular portion should be broken, or if it were to be sprung out of true the entire fixture would have to be scrapped. Furthermore, the casting is more difficult to

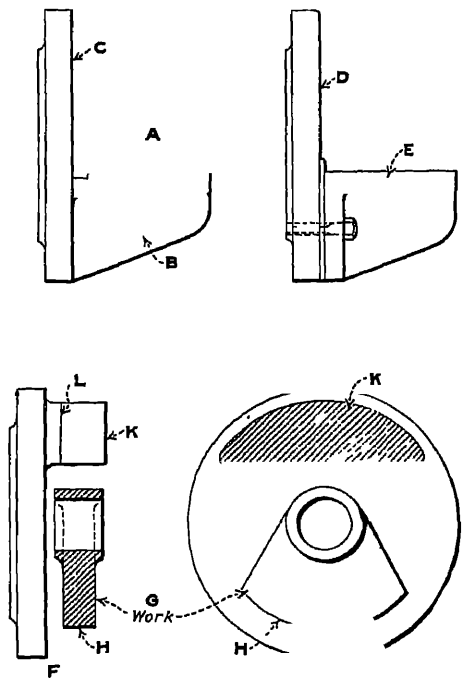


FIG. 32.—Construction of fixtures.

make when in this form, than if a construction like that shown at *D* were to be used. In the latter case, the angular portion is made up as a separate member *E* and fastened to the faceplate. In a like manner, locating pads or surfaces can often be made up separately in the form of steel rings or steel blocks, as may be required, these being fastened to the face of the fixture in order to provide for up-keep in case of injury.

Fixtures which are made to hold an irregular piece of work having considerable weight at one side of the center are frequently counter-balanced, particularly when they are to run at

igh speed. An example which illustrates the proportioning of a ounter-balance is shown at *F*. The work *G* has a heavy portion *I* eccentric to the center hub, and on account of this a counter- alance should be provided, as shown at *K*. In making up this ounter-balance, it is usually better to make it up as a separate nit and fasten it to a pad on the fixture, as at *L*. Care must e taken in proportioning it so that it will have more than enough ietal to offset the portion of the work which is being balanced; hen after it is placed in position with the work on the fixture, it an be drilled out, chipped or faced off so that it balances the ork perfectly. It is possible to make a counter-balance in such shape that it is adjustable, so that several pieces of the same haracter can be held on the same fixture, by adjusting the eight.

It is well to avoid the use of very heavy masses of metal in ixtures of this kind, and it is better to make provision for sta- ility by means of ribs. It is not good practice, however, to have hese ribs project from the fixture so as to cause trouble to the oper- tor and to endanger him. It is frequently possible to cast a narrow im around the fixture, leaving the outside smooth in order to guard gainst accidents. If all clamps, bolts and screws are kept below his surface, the fixture will be much better for the operator and resent a cleaner and more workmanlike appearance.

Use of Soft Chuck Jaws.—Chuck jaws which have not been ardened are often used for second-operation work, being bored out o a diameter such that they will fit the work on some portion vhich has been previously machined. The method of holding by neans of soft jaws cannot be considered as strictly accurate, due o variations which are likely to be found in the chuck itself, and aused by wear on the scroll ring and also on the teeth cut on the aws where they mesh with the ring. There is also a certain mount of "back lash" in nearly all chucks which are not new, nd this matter also may cause slight inaccuracy. Soft jaws are, owever, very convenient for certain classes of work and can be sed in many cases. It is a matter of judgment regarding the ccuracy required when deciding whether to use this method of olding. One of the advantages of soft jaws for second-opera- ion work is the fact that they can be trued up and bored out in osition with considerable accuracy. The method used is to hold piece of cylindrical work in some portion of the jaws which is ot to be bored, and grip it tightly by means of the jaws so as to

take out any back lash that might otherwise cause trouble. When the jaws are in this position they should be bored to the exact size of the work which they are to hold. After this is done the chuck should not be removed from the spindle center, and no change is to be made in its location with respect to the spindle.

Soft jaws are used on both two-, three- and four-jaw chucks, but less commonly on the two- and four-jaw variety. They are generally made of cast iron or machine steel, depending on the

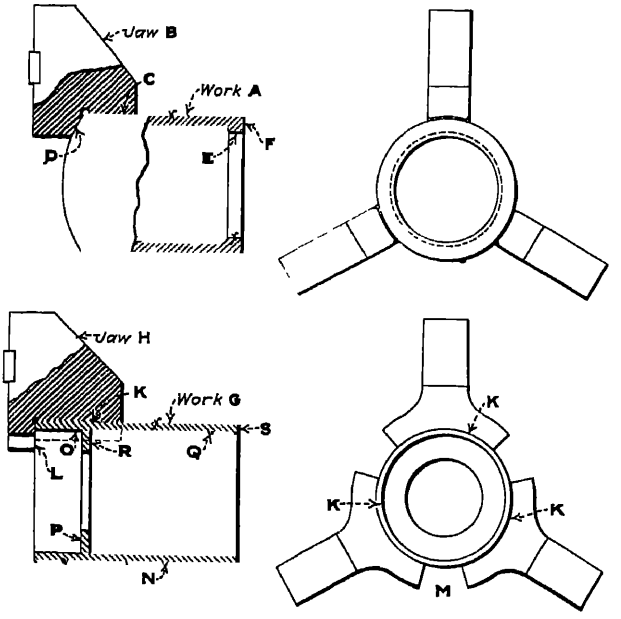


FIG. 33.—Use of soft chuck jaws.

requirements, and somewhat upon the size of the chuck on which they are used. For a great deal of work, cast iron gives perfectly satisfactory results, although some users prefer machine steel. Jaws are generally made in a form such that they can be attached to the regular jaws of the chuck by means of screws.

In the example shown in Fig. 33 the work *A* has been previously machined on the outside and the curved end. Therefore, the jaws will be bored out at *C*, and formed at *D* to act as a seat for the end of the casting. The operation for which the jaws are made is the boring of the portion *E* and facing it at *F*. After this operation, the casting is to be refinished on the outside

diameter, and all subsequent operations locate from *E* and *F*. For the condition shown, very satisfactory work can be obtained by this method; and due to the general construction of the casting, there is no possibility of distortion. It is possible to make up jaws of a similar kind but with soft portions inserted, so that replacements can be easily made. This, however, is not commonly done, as the method shown is cheap and generally satisfactory for the majority of cases. When a chuck is to be removed and replaced frequently, as might be the case when small lots are being manufactured, it might be more profitable to use inserted jaws. The designer must be governed by conditions in determining which type to use.

In holding thin work in soft jaws, there is always more or less

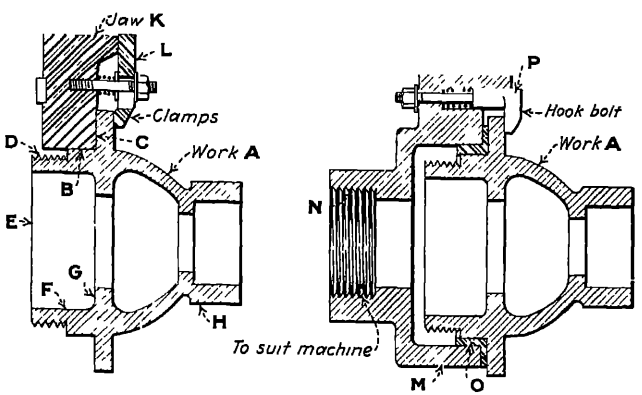


FIG 34.—Two methods of holding same piece of work.

danger of distortion, as has been previously mentioned. An example of this is shown in the work *G*, which is a thin cast-iron sleeve previously machined at *N*, *O* and *P*. This casting is so thin that it would be distorted if held by a method like that shown for the work *A*. By making jaws of special form with large ends, as shown in the view *M*, a large part of the circumference will be enveloped by the jaws, and thus prevent crushing or forcing the casting out of shape. The jaws *H* are bored out at *K* to the diameter of the work and a seat is provided at *L*. In using these jaws, the surfaces *Q*, *R* and *S* can be easily machined without danger of distortion. This is an example where the large ends of the jaws could be made of separate pieces and fastened to the regular jaws, if it seemed desirable.

Many times there are several methods which can be used for holding a given piece of work, no matter whether it is a first- or second-operation job. Sometimes there is a choice between the methods, both as regards economy and also the accuracy obtained. Fig. 34 shows a piece of work *A*, which has been previously finished at *B*, *C*, *D*, *E*, *F* and *G*. The requirements of the work are that the portion *H* must run concentric with *B* and be square with the flanged portion *C*. In the first method suggested the work is held in soft jaws *K* in a three-jaw chuck. The jaws are bored out so that they fit the portion *B* of the casting. In order to make sure that the flanged portion *C* is square, clamps are provided at *L* directly at the jaws themselves. Provision is made in the clamps so that they can be slid back away from the work when removing and replacing it.

As previously mentioned, there is a possibility of inaccuracies resulting from a method of holding like this. Therefore, it was decided to use a fixture in place of chuck jaws. This fixture is shown at *M*. It is bored out at *N* and threaded to fit the end of the spindle, but it could readily be made so that it could be applied to an adapter. In locating the work, a hardened ring is used at *O* and the work is clamped back against the ring by means of hook bolts at *P*. These are three in number and operate from the back of the faceplate. This construction makes a clean-appearing fixture, and one which has no projections likely to catch on the clothing of the operator. The steel locating ring *O* can be ground to size in place on the machine, and it can be readily replaced in case of inaccuracy.

It is sometimes necessary to hold a piece of work for a second operation when it is difficult to grip it securely by means of clamps in a fixture. A case in point is shown in Fig. 35 which illustrates the method that.can be used to take care of a condition of this sort. The work *A* has been previously machined in the hole *B* and also at *C*, *D* and *E*. It is necessary to grip the work firmly at *D* and at the same time locate it on a plug at *B*. As there is a possibility of a slight variation in the concentricity of *D* and *B*, it is necessary to make the method of holding at *D* so that it will take care of any variations at this point. By using a standard type of three-jaw geared scroll chuck, such as that shown at *F*, the work can be gripped firmly by making slight changes in the chuck. The scroll ring, shown in detail at *G*, must be taken out of the chuck, bored out at *H* and turned down

at K, so that these sizes are, respectively $\frac{1}{32}$ in. over and under their former sizes. This permits the chuck to float slightly, and

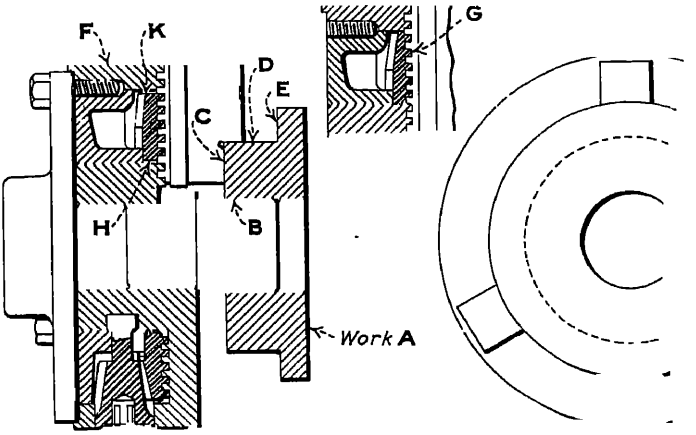


FIG. 35.—Chuck fitted with floating scroll.

thus equalize any variations in the casting, and yet at the same time hold it very firmly. This method of holding has been used by the writers in several cases with very satisfactory results.

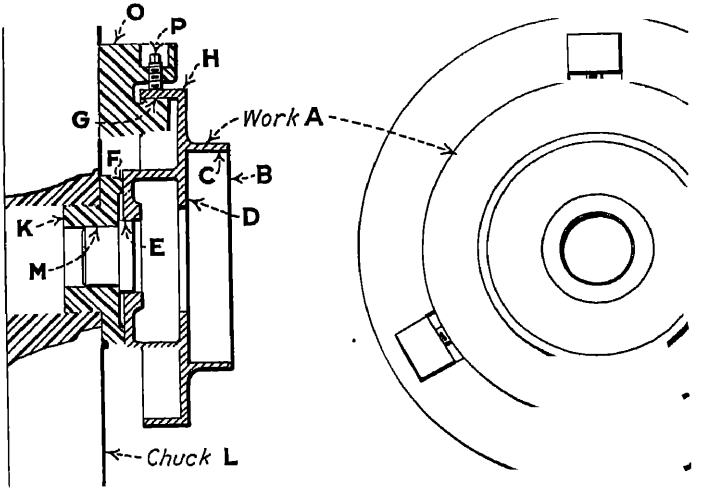


FIG. 36.—Application of a floating scroll chuck.

In applying the principle of the floating-scroll lathe chuck to the handling of work which has been previously machined, the

nature of the work must be carefully considered. The portions which are to be held by the chuck jaws may be finished or in the rough. If in the rough, there may be considerable variation which might not be taken care of by $\frac{1}{32}$-in. float in the scroll. If, however, the work is located for a previous operation by surfaces approximating those which are to be used for the second holding, then in all probability the amount of float mentioned will be sufficient to take care of variations. It is advisable wherever possible to grip the work by a previously finished surface, which will naturally be approximately concentric with the other portions. When this is done, there is little chance for trouble, and satisfactory results can be obtained without difficulty. Fig. 36 shows a piece of work *A* which is to be machined at *B*, *C* and *D*. The piece has been previously finished in the hole *E* and it has been faced and turned at *F*, *G* and *H*. Due to the fact that the entire casting is somewhat fragile in construction, it might easily vibrate considerably unless so held as to eliminate any trouble of this kind.

A locating bushing *K* is fitted to the center hole in the chuck *L*, as shown. This bushing has a flange on which the work rests at *F*, and it is also fitted with a plug *M* which enters the hole *E* in the work. Special jaws *O* are so arranged that they grip the thin flange in three places on the inside at *C*, the float of the scroll allowing them to adjust themselves to any slight variations in concentricity. These jaws are not strictly used for centering the work, but only for holding it to prevent vibration. Therefore they should not be brought up tightly, but only with sufficient pressure to make sure of a contact. After this is done, the setscrews *P* are tightened with a socket wrench, thus obtaining a metal-to-metal contact which gives an excellent drive for the work and prevents vibration.

The two examples given of the use of a floating scroll chuck are sufficient to illustrate its advantages. It should be noted, however, that any chuck in which the scroll ring has been refinished so that it will float, cannot be used for centering and holding work of the ordinary kind.

Simple Fixtures for a Flange.—In Fig. 37 is shown a piece with a form somewhat similar to that just illustrated, but here the work *A* has been machined on the inside in a previous operation, and it is necessary to hold it by the portion *B* in order to machine the end *C*. This is another example of a fixture designed to be

screwed directly to the end of the spindle, yet it could be mounted on an adapter if desired. The work locates on a plug *D* and rests on three hardened pins *E* in the body of the fixture. These pins strike against the finished surface of the flange and serve also to give correct end location to the work, so that the end *C* will be machined in a fixed relation to the flange, and will at the same time be concentric with the portion *B*. A simple method of clamping is used in this case, the clamps being shown at *F*. In order to keep the outside of the fixture clean and avoid trouble

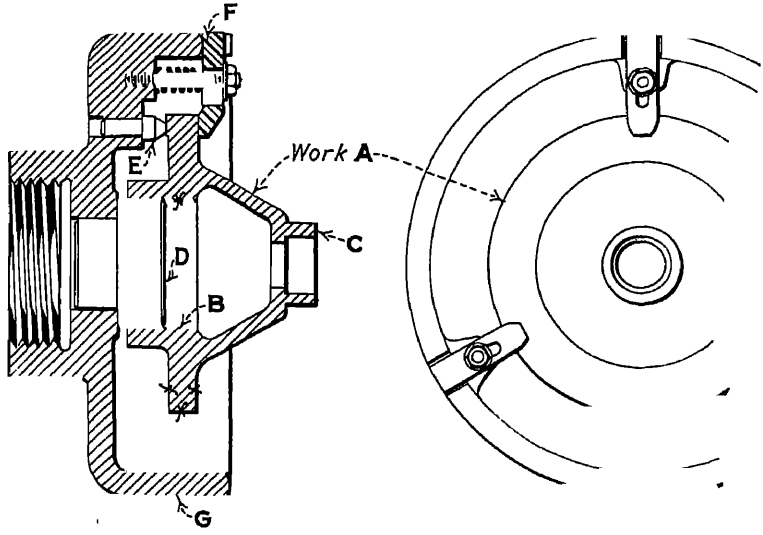


FIG. 37.—Second-operation fixture for a malleable-iron flange

which might be caused by a projecting flange, the outer portion of the fixture is carried up in the form of a ring *G*, which is slotted to receive the ends of the clamps, as indicated. This is a type of fixture which is simple and efficient; and for other similar conditions the principles shown here can be applied.

In Fig. 38 is shown another method which can be used to grip and drive work that has been previously machined, and that is located in a central position by means of a plug or ring in a previously finished hole. The work *A* has been machined at *B*, *C*, *D* and *E* prior to the operation indicated. It is necessary to locate it by the inside surface *B* and by the end *C*. The work to be done in this operation is the facing of the surface *F* and the machining of the portion at *G* and *H*.

A standard faceplate K is used for the work. It is fitted with a locating ring L on which the work is placed. There are four standard faceplate jaws M mounted in the slots on the faceplate. These jaws are cut out as shown, so that they will form an end stop for the portion C of the work. They also grip on the outside surface D. The standard jaws are operated independently by means of screws, so that they come up against the outer flange and hold it tightly against the locating ring. This method gives ample driving power so that the work can be held without danger of its moving under the action of the cutting tools. Another advantage is that the metal-to-metal method of gripping

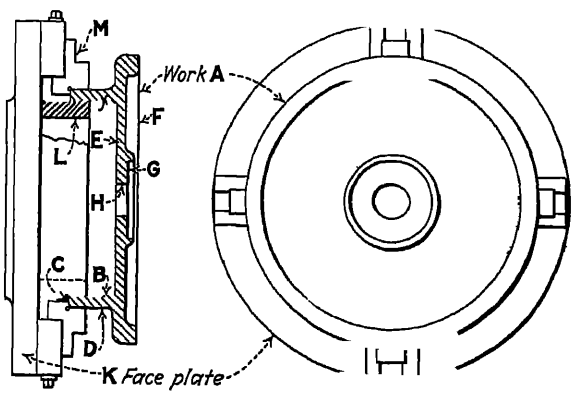


FIG. 38.—Standard faceplate used as a fixture.

kills vibration and prevents chatter. The only objection to this scheme of holding is the fact that it is somewhat slow, as each one of the jaws is set up separately. It is, however, quite cheap and can be adapted to a number of conditions of a similar kind.

Fixture for a Ball Pipe Joint.—When work of a spherical nature is to be held, considerable care must be used in the design of the fixture. In the first place, the seat on which the spherical portion rests must be formed out so that it will fit the work closely. In the example shown in Fig. 39 the work A has been previously finished on the spherical end. The other end B is to be faced at C and D in the operation shown. A fixture F is mounted on the adapter E and provided with four inserted jaws C. These jaws are wide enough so that they each have a contact of about 60 deg. on the outside of the spherical portion of the work, which they are bored out accurately to fit. The fixture F contains four toggles H

which are mounted on pins at K. There is a small amount of float allowed on these pins in order to equalize any roughness on the inside of the casting. Coil springs are provided at L in order to throw the toggles toward the center, so that the work can be removed when desired.

The bar M extends through the spindle and is operated by a handwheel at the rear end. When this bar is thrown back between the toggles the tapered portion forces these outward and at the same time pulls them back, so that they contact with the inside of the casting and hold it back firmly against its seat. In connection with this device it is necessary to use a centering plug,

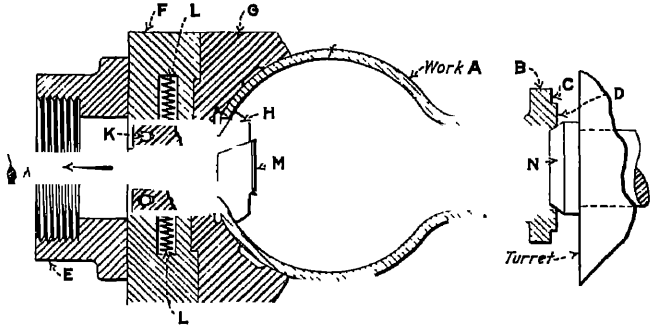


FIG. 39.—Fixture for a ball pipe joint.

such as that shown at N in the turret. It is brought up and remains in the position shown while the clamps are being tightened, after which the turret is backed away and the tools used for the work operate in sequence. A centering device of this sort is often necessary when holding work during the operation of chucking.

There is an old saying that people learn more from their failures than they do from their successes. This is quite evident in tool work, for a man who has designed any kind of a mechanism which does not work properly and which gives trouble in operating, will be sure to hear about it in an unpleasant manner. If he is at fault in his design he will appreciate the trouble caused and will remember the conditions, so that he is unlikely to make the same error again. This is a costly method of learning how to do a thing correctly, and an example of a successful and an unsuccessful design is given herewith to bring out the point forcibly.

In Fig. 40 is shown a piece of work *A* which has been previously machined on the outside portion *B* and also at the end *C*. The curved end *D* is to be machined in this setting. A special form of spring collet *E* is mounted on an adapter *F* which is screwed to the spindle. The rod *G* is used as an ejector to force the work out of the chuck after it has been machined. This rod is operated by a collet mechanism at the end of the machine. The portion *H* is split in eight places, so as to allow it to spring as contracted by the nut *K*, which operates on the tapered thread. It was the intention of the designer to make this in such a way that by placing a pin in the holes shown, the collet would be contracted by the revolution of the ring according to its position on the tapered thread. The design however is faulty, and a great deal of trouble was experienced in operating it. It was practically impossible to contract the chuck sufficiently to hold the work and there was a great deal of friction on the threads, which doubtless had considerable to do with its faulty operation.

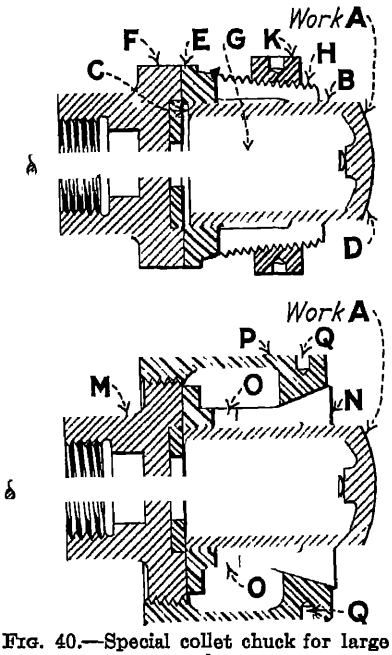


FIG. 40.—Special collet chuck for large work.

Another design, also shown, was made to take its place, the operation of the new device being perfectly satisfactory. In this case the adapter *M* was fitted with a spring collet *N* having a tapered end. This collet was split in twelve places and large holes were drilled at *O* in order to give more spring to the collet jaws. The operating sleeve *P* was threaded to the adapter as indicated. In operating the device, the revolution of the sleeve *P* was accomplished by means of pins in the holes *Q*. The tapered portion caused the collet to contract and hold the work rigidly. An ejector was provided similar to that shown in the other example. In this design a great deal of the friction which

was caused by the tapered thread was overcome. The action was much smoother and the chuck was easier to operate.

When several pieces of the same general character but of different diameters are to be held in a fixture, it is sometimes possible to design this so that adjustments can be made to suit the various pieces. Even in cases when production is high, it might be advisable to follow this method and make up several fixtures of the same kind, adjusting them for the different pieces as required. By an arrangement of this sort the same patterns can be used for all of the fixtures; and the other parts, being uniformly

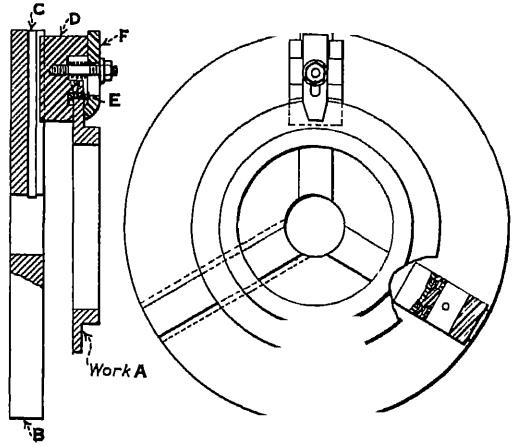


FIG 41 —Special fixture for different sizes of work.

designed, could be manufactured cheaper than if three or more fixtures all different and made from separate patterns were built.

An example of this kind is shown in Fig. 41. There were a number of pieces like the work shown at *A*, the pieces being practically the same except that their diameters varied considerably. A special faceplate *B* was made up and mounted on an adapter. It was slotted in three places, as shown at *C*. The slots were made up in T-form to receive keys, and the three jaws *D* could be adjusted readily in these slots to the diameters required for the different pieces of work. Several rings or grooves were scored on the face of the plate, so as to give the approximate position for each diameter required. The work to be handled is located in soft inserted jaws, shown at *E*. These jaws are bored out in place on the fixture, according to the diameter

which is to be handled. The work is placed in these locating jaws and clamped in place by means of the sliding clamps *F*. The fixture is inexpensive and simple in design. It is often possible for the designer to effect substantial economies in the use of fixtures by a method similar to that shown, and therefore it is the part of wisdom to consider any pieces of similar character which are to be handled in the same general way, before proceeding with the design of the fixtures.

In setting up a piece of work which is to be turned eccentric to some previously finished surface or hole, care must be used in the design to make sure that the center of rotation is correct, in order to produce the desired results. The matter of location

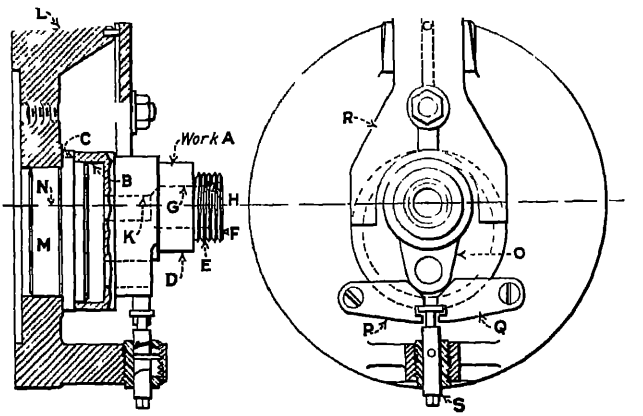


FIG. 42.—Chucking fixture for an eccentric casting.

is important, and the method of clamping must be carefully studied, so that there will be no tendency to force the work out of position and thus produce an eccentric which is not in the right relation to the hole from which it is located. There are a number of ways in which an eccentric fixture can be made, but much depends upon the nature of the work and the degree of eccentricity required. Sometimes it is necessary to machine two surfaces in the same setting, and a fixture must be designed which can be indexed or thrown over from one position to another during the progress of the work. Fixtures of this kind will be discussed later.

The example shown in Fig. 42 is a piece of work *A* which has been finished at *B* in a previous operation. The end *C* has also

been faced. It is necessary to machine the portions *D*, *E* and *F* and the interior surfaces *G*, *H* and *K* eccentric to the hole *B*. The fixture *L* is mounted on an adapter which screws on the end of the spindle. The locating plug *M* is placed eccentrically to the center of rotation of the fixture *N*. The portion to be machined is eccentric in the direction of the lug *O*, which thus provides a convenient method of locating the work. The arrangement used for the purpose consists of a pair of swinging arms *P* and *Q* operated by a screw bushing and bayonet-lock device, which has been previously described under the subject of drill jig design. The work is clamped in place by a large special clamp *R*, which straddles the hub and bears on both sides of it in line with the center of the work which is being machined. In considering the features of design brought out in this fixture, attention is called to the projecting screw at *S*. This would not be considered good design, unless some protection were provided so that the screw would not be likely to catch on the clothing of the operator. Provision should be made to prevent such an occurrence, by making a guard around the fixture, or using a piece of sheet metal fastened to it in such a way as to protect the end of the screw and yet leave it free so that a wrench can be applied without difficulty. The matter of protection to the operator should never be forgotten by the designer. Fixtures are usually improved as to their appearance also if care is taken to avoid all projecting lugs, clamps and screws. Furthermore, production is probably increased to some extent, because the operator is not afraid of being caught on any projections.

CHAPTER IV

DESIGN OF SPECIAL FIXTURES

SECOND OPERATION TOOLING ON SPECIAL WORK—SLIDING INDEX, ANGULAR, COUNTER-BALANCED AND OTHER SPECIAL FIXTURES—CLOSING-IN DEVICE FOR OUTSIDE HOLDING—SPECIAL FACE-PLATE FIXTURES—OUTSIDE HOLDING FIXTURE FOR THREADED WORK

In Fig. 43 is shown a piece of work *A* which has been previously faced at *B* and which is to be machined at *C*, *D* and *E*. The hole

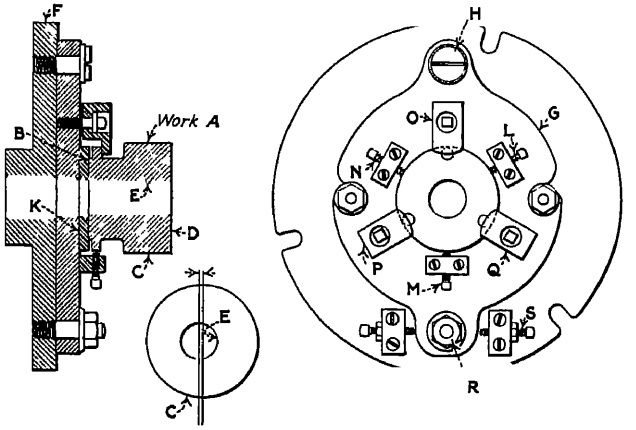


FIG. 43.—Eccentric fixture with swivel member

E is slightly eccentric to the portion *C*, as indicated in the diagram The fixture body *F* may be mounted on an adapter or screwed to the spindle, as desired. The member *G* is mounted on *F* so that it swings on the shouldered screw *H*. The work is located on the hardened plate *K* mounted on a swiveling member, and its position is determined by means of the three screws, *L*, *M* and *N* These screws are mounted in steel blocks suitably located. The work is held down by the three clamps at *O*, *P* and *Q*, these clamps being operated by a socket wrench. After the hole has been machined, the nut *R* is loosened and the swivel is moved

over until it strikes the stop screw at *S*. This distance can be accurately determined by using a size block.

A point of importance in connection with a fixture of this sort is the location of the stop screws in relation to the center and to the pivot screw *H*. It is advisable to make the distance the same on each side of the center, so that the eccentricity obtained will be exactly half of the movement between the stop screws. The simplicity of fixtures of this sort for work which has only a small amount of eccentricity makes them very desirable, as their construction is such that they can be made up cheaply. A sliding fixture can be designed which will give the same results, but its

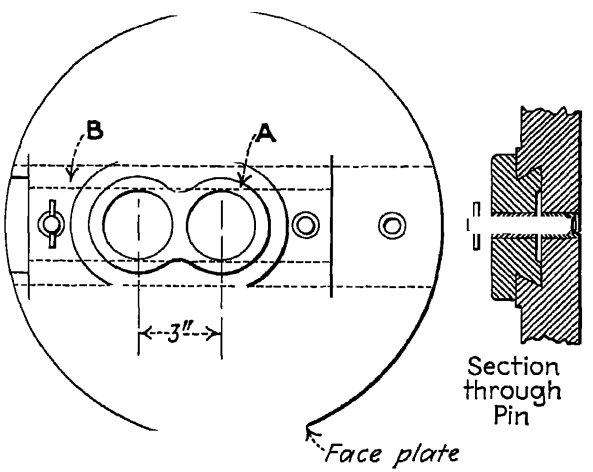


FIG. 44.—Principle of sliding-index fixture.

cost is somewhat more, due to the necessity for fitting the slide.

In making up a fixture for a piece of work which requires two holes to be put in at some distance from each other, a sliding fixture can be used. A diagram to illustrate this kind of a condition is shown in Fig. 44. The work in this case is a casting *A* having two holes of different sizes 3 in. apart and parallel to each other. The illustration is simply intended to represent the problem in diagrammatic form, in order to show the conditions which are found. The faceplate is made up in such a way that a slide of the dovetail variety is mounted on it at *B*. The work is clamped by some convenient method to the slide, and locations for the two holes are obtained either by means of plugs entering

bushings or by stop screws suitably arranged. If work is very much heavier on one end than on the other, it may be necessary to arrange some kind of a counterpoise to keep the fixture in proper balance, but unless high speed is to be used this might be found unnecessary. Sliding fixtures of various kinds can be made, according to the nature of the work and the amount of eccentricity required. In locating any piece of work from a tapered hole care must be taken to make the tapered member so that it will float. If this is not done slight variations between the taper and the other finished surfaces may result in an improper location and cause inaccurate work. The flywheel shown at *A* in Fig. 45 is an example of this kind. The work has been previously

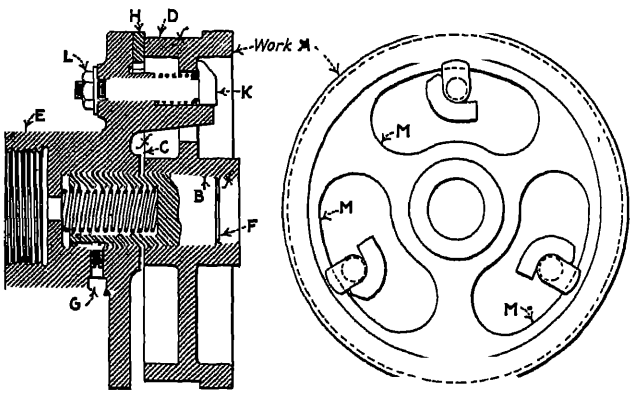


FIG. 45.—Second-operation fixture for flywheel.

finished in the tapered hole *B* and also at *C* and *D*. The fixture *E* is designed to be screwed directly to the spindle, but it can also be mounted on an adapter if desired.

The work locates on the taper plug *F*, which is so arranged that a coil spring keeps it in contact with the hole during the chucking operation. It is restrained so that it does not travel too far, by means of a screw *G*, which enters a slot on the outside of the plug. The finished rim on the flywheel locates on a hardened ring *H*, against which it is clamped by means of hook bolts *K*. These hook bolts are operated from the back of the fixture by means of nuts at *L*. The nature of the casting gives an excellent opportunity to apply this method of clamping, as the hook bolts extend up through the cored holes *M*, in the casting leaving room enough

so that when the bolts are turned around the casting can be removed readily.

In clamping the work down by means of the hook bolts, the taper plug remains firmly in contact with the hole and adjusts itself when the clamps are tightened. If there is any variation between the taper and the finished surface *C*, it will be taken care of if this method is used. A screw taper plug can also be used in place of the spring plug, but this is not as good practice, as it depends upon the operator's "sense of touch" and he is likely to

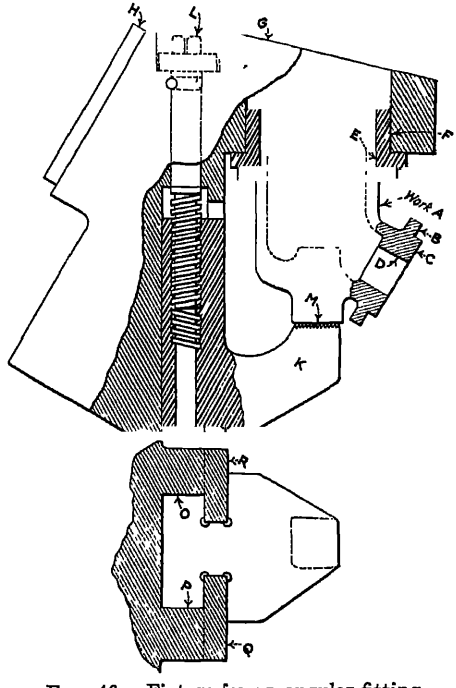


FIG. 46.—Fixture for an angular fitting.

force the plug into the taper too far or too little and thus cause inaccurate work.

Fixture for an Angular Fitting.—In Fig. 46 is shown the principles of a fixture designed for holding a piece of angular work *A* while machining the portions *B*, *C* and *D* in a definite relation to a previously finished portion *E*. This example is given to illustrate a principle rather than to show the complete design of a fixture. The work locates in a bushing *F* in the body of the fixture *G*. The

fixture is mounted on an adapter by means of the finished ring at *H*.

The method of clamping the work is by means of a sliding jaw *K* operated by a special screw *L*, using a socket wrench. This jaw comes up against the end of the casting at *M*. If the casting is rough it might require a swivel jaw at this point too; but if it has been finished a plain jaw will answer the requirements. The jaw is fitted to a slide, as shown in the end view at *O* and *P*. For the majority of work it would be possible to cut this slide directly in the casting. A better construction is to make two strap clamps at *Q* and *R*, fitting these to the slides where necessary. Angular work of this kind is encountered from time to time, and the

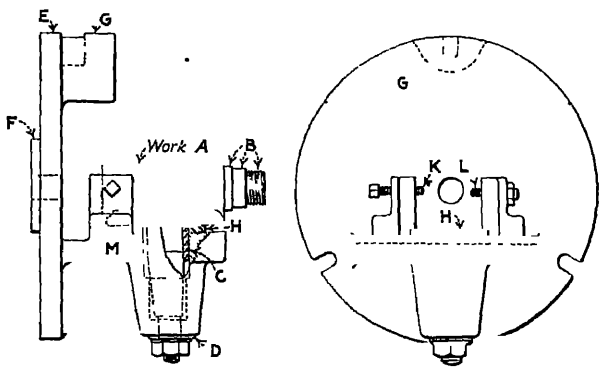


FIG. 47.—Counterbalanced fixture for steering knuckle

designer should study methods which can be applied to suit peculiar conditions.

Counter-Balanced Fixture.—An example of a fixture having a counter-balance is shown in Fig. 47. The work *A* is to be machined in this operation on the end *B*. The spindle end, which is at an angle to the part to be machined on the counter-balanced fixture, has been machined in a previous operation, so that it is necessary to provide a means of locating the piece from it. The fixture *E* is so designed that it can be attached to a faceplate, locating in the hole by means of a flanged portion *F*. Provision is made so that T-bolts can be used in the slotted portions of the fixture to hold it back against the faceplate.

The work locates in a hardened bushing at *C* and on a ring at *H*. It is drawn down on the surface of the ring by means of a nut at *D*. The finished surface of *M* is at an angle of 1½ deg. with the

center of the fixture; and as made here M is cast as a unit with the remainder of the fixture. It might be more economically made and easier to machine if it were made in bracket form and screwed and doweled on to the body of the fixture. The work is held in its correct location by means of a setscrew at K, the action of which tends to throw it over against stop L, which is made adjustable in order to allow for making changes that may be required by variations in the castings. The counterbalance G is also made as a part of the fixture, and it would naturally be drilled out or faced off so that it will balance the opposite side with the work in position. It might be possible to design this part also as a separate unit, and fasten it to the body of the fixture by means of bolts.

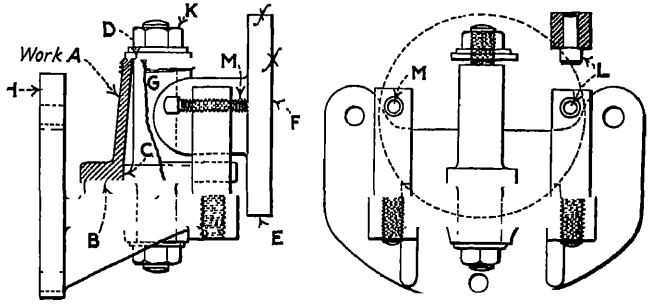


FIG. 48.—Special fixture for swivel bracket.

Another method which can be used to hold work of this kind would be to make the counterbalance G and the bracket M in such shape that they can be fastened to a standard faceplate, in which case no fixture would be required other than the parts mentioned. This practice would not be considered very good unless the faceplate were kept as a unit with the fixture, because of the possibility of errors arising from resetting the parts on the faceplate.

Another special fixture which can be attached to a faceplate is shown in Fig. 48. The work A is a swivel bracket which has been machined in a previous operation at B, C and D. It is required to machine the surfaces F and E in a certain relation to the other portion, and in order to do this the fixture shown was designed. The body of the fixtures H is provided with three holes, so that it can be fastened to a standard faceplate. The plug G is set in an angular bracket so that the work locates on it, and is held down against the hardened ring by means of the nut

and C-washer K. The finished surface of M is at an angle of 1½ deg. with the center of plug G. The location of the large end is obtained by swinging the flange against the stop L by means of the screw at M. This fixture allows the tools to operate in turning the portion E and F without interference. The work is held rigidly and its location is fixed so that the proper relation is obtained between the various surfaces.

Pot Fixture for a Stamping.—An unusual fixture is shown in Fig. 49, in which the work A is a steel stamping, 12 in. in diameter. The outside of this stamping B is held closely to size and the work which is to be done is the turning of the portion F, facing of E, boring of D and back facing of C. It was desired to do this in one operation and the fixture was designed for this purpose, special

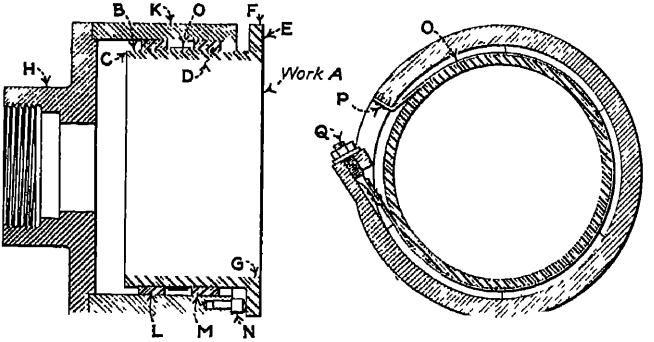


FIG. 49.—Pot fixture with steel strap clamp.

tools being used for the back-facing operation. The fixture H is screwed to the spindle of the machine and a ring K is fastened to it. The inside of this ring is provided with two other hardened rings L and M which are ground to such a size as to allow the work to fit into them freely. The work is placed in the fixture until it rests against three locating studs N, which determine the end location. For driving the work, a thin springsteel ring O is fastened at P and passes entirely around the drum, against which it is drawn up snugly by means of a nut at Q. This band has a contact against nearly the entire surface of the drum and gives sufficient driving power to withstand the pressure of the cut.

Work which has been previously machined sometimes requires another operation on it of drilling or hollow milling. When this portion must be held carefully in relation to the previously machined part, provision should be made to guide the drill or

hollow mill. An example of this sort is shown in Fig. 50, in which the work *A* has been machined in a previous operation as shown by the finish marks on the large end. The fixture *B* is designed to fit into an adapter fastened to the spindle. The work locates in a hardened ring *C* in the body of the fixture. It is held in place by means of the two hook bolts, *D* and *E*, the arrangement of which is such that they can be operated very rapidly. Swivel C-washers *F* are used under the heads of each of the bolts *G*, being attached to the hook bolts as shown. One side of the fixture is carried up at *H* to form a bracket in which the guide bushing *K* is located. This guide bushing serves to locate a combination hollow mill and facing tool which is used to machine the stem *L* and the surface *M*,

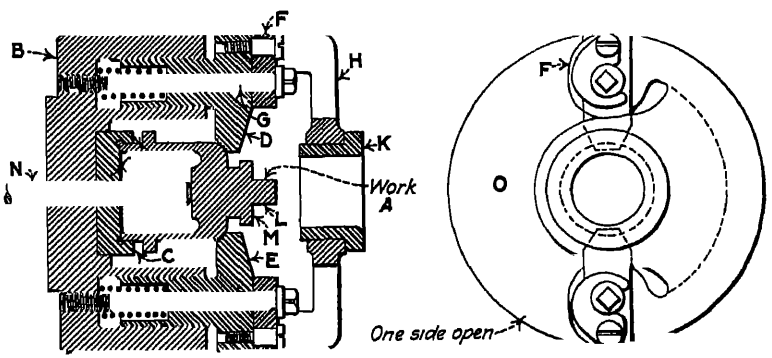


FIG. 50.—Special fixture with guide bushing.

these two portions being required to be concentric with the other end which has been previously finished. In removing the work from the fixture, the bolts *G* are unscrewed slightly and the C-washers thrown back, which allows the hook bolts to spring out until restrained by the collars on the bolts. An ejector is provided at *N* to knock the piece out of the locating ring. One side of the fixture is open at *O* so that the operator can easily reach in and remove the work.

In making up fixtures which carry guide bushings for any sort of cutting tools, care must be taken both to provide plenty of room for chips and to give ample hand clearance so that the work can be easily removed and placed. The support for the bushing must be sufficiently rigid to withstand any pressure developed by the cutting action. In cases where cutting lubricant is to be used, provision should be made for it either by carrying the liquid

through the tool or by having openings through the fixtures so that the fluid can easily reach the work.

In Fig. 51 is shown an example of a piece of work *A* which has been previously machined at *B* and *C*, and must be held for the operation indicated by means of the previously machined surfaces. A special form of closing-in device is used for the purpose. The end of the spindle is furnished with a nosepiece *D*, this being made of steel hardened and ground. The work is to be machined on an angular surface and at the end *A* in this operation, so that it is necessary to make the holding device in such a way that it will not interfere with the cutting action of the tools.

A special spring collet *F* is ground to fit the portion *B* and to a taper corresponding with the angular surface *E* in the nosepiece.

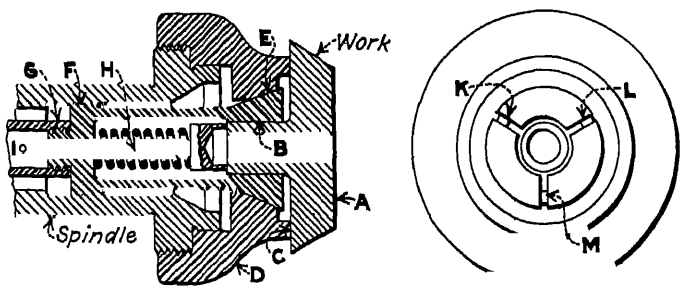


FIG. 51 —Closing-in device for outside holding.

This collet is split in three places, as shown in the end view at *K*, *L* and *M*. It is operated by means of the lever at the end of the machine through the sleeve *G*, which connects with the collet mechanism. The device is provided with a knockout *H* which operates automatically by means of the coil spring shown. In setting up this piece of work, a plug is placed in the turret of the machine, and is brought up against the end of the work until it strikes the end of the nosepiece at *C*. The operator holds it there while operating the collet mechanism, after which the turret is indexed and the cutting tools are brought up as needed.

A knockout device such as that shown may be found very convenient for any work which cannot be easily removed from the fixture, and numerous applications of a principle similar to this can be used on various types of fixtures. It is usually necessary when a fixture is equipped with a spring knock-out to use the turret to hold the work in place, so that the spring will not tend to force it out of position while chucking.

In holding a long piece of work having a finished surface of considerable length on which it is necessary to grip it during the holding operation, a somewhat different method may be necessary from those that have been previously shown. An example of this sort is shown in Fig. 52, in which the work *A* is a projectile on which the outside work has been done in a previous setting. The work must be located by the outside finished surface for the operation of boring the inside *B*. Furthermore, the concentricity of the outside and inside is important, so that the closing-in device must be very accurately made.

The fixture *E* is so made that it fits an adapter at the point *F* and is secured to it by means of four screws as shown. An end stop for the projectile is provided by boring out the inside surface *K* to the same form as that of the end of the work. In

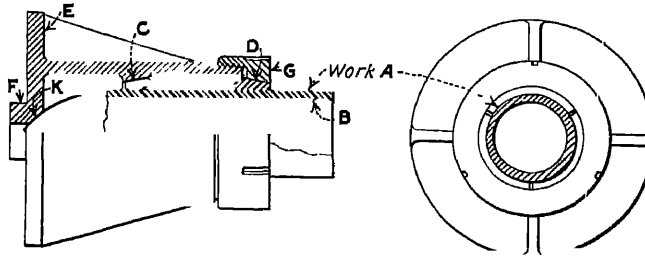


FIG. 52.—Double-end closing-in device for projectile.

placing the piece in position in the chuck, it is held back against this seat while tightening the collar *G*. This collar is ground to a taper on the inside, so that it fits the corresponding taper *D* on a spring collet of special form. The other end of this collet at *C* fits a tapered portion in the inside of the holding device. The collet is made of tool steel and split in six places, three from each end, so that it will expand and contract evenly. A special device of this kind is useful when a piece of thin work is to be handled, as it does not distort the work, yet it holds it with sufficient pressure to enable the machining work to be done.

We have dealt largely in the previous descriptions with the location of work from surfaces more or less concentric with those which are to be machined. The example shown in Fig. 53 is a radical departure from those mentioned in that the work *A* is a drop-forged lever which has been previously bored and reamed at *B*, and which has been milled on the surfaces *C* and *D*.

The fixture shown was designed for the boring, reaming and facing of the large hole. The requirements of the work are that the distance between the hole *B* and the large hole in the hub shall be held closely to size and that they shall be parallel to each other. The fixture *E* is a casting, which is recessed at *G* so that it can be fastened to an adapter, as indicated by the dotted lines. The work is located on a hardened plug having a shoulder at *F*, this end of it being held down by means of a nut and washer as indicated.

The large hub locates on a hardened bushing *H*, which also acts as a pilot bushing for the tools used in generating the hole.

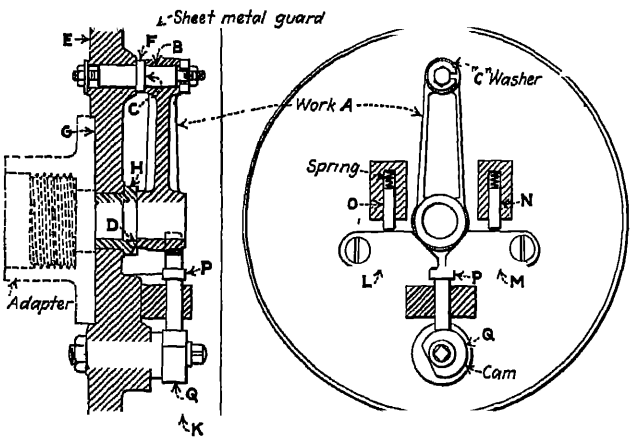


FIG. 53.—Faceplate for second operation on drop-forged lever

In order to locate this end of the work centrally, two swinging arms *L* and *M* are used, being cut away where they come in contact with the work, so as to form a "V." The two members *L* and *M* are so positioned on the fixture that they come above the parting line of the forging and are in contact with a slightly angular surface of the hub, which tends not only to locate the hub but to hold it down slightly against the surface of the bushing *H*. The two arms are operated by means of a plunger *P* which is set up by means of a cam at *Q*. There are two plungers *O* and *N* controlled by coil springs behind them, and these plungers throw the arms *L* and *M* out away from the work when the cam is released.

This fixture is of clean design and there are several good points in its construction. The type of V-block used has been described

previously. Due to the fact that protection is required for the outside of the fixture, a sheet-metal guard *K* is applied, so that it surrounds the entire fixture and guards the workman from injury. An additional advantage in this guard is that it prevents the lubricant from flying on the operator, as it might otherwise do if no protection were provided.

Holding a Thin Casting.—In Fig. 54 is shown a condition somewhat out of the ordinary. The work *A* is a thin casting which is to be machined in the central tapered hole and on the outside

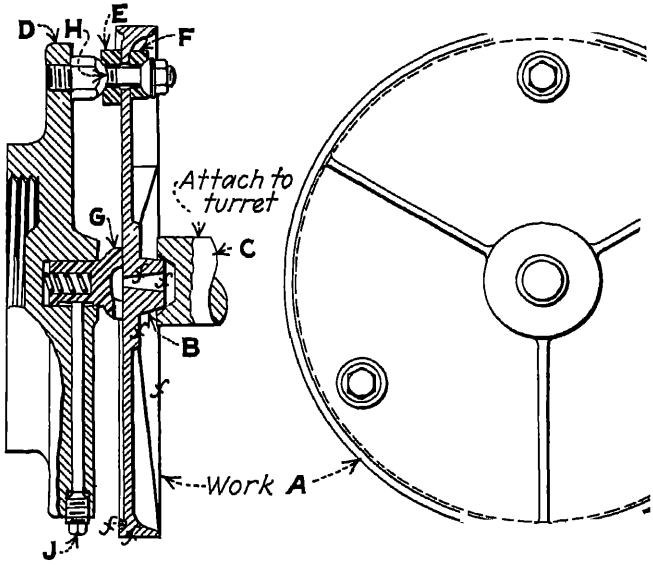


FIG. 54.—Faceplate for holding a thin casting.

diameter; and also an annular groove is to be cut at the back of the flange as shown by the *f* mark. The work is set up for the operation on three washers *E*, these being so arranged that they will rock on the spherical surfaces *H* so as to equalize any roughness in the casting at the points where they come in contact with it. Similar washers are provided at *F* for the same purpose.

In locating the work, the turret is furnished with a special locating bushing, as indicated at *C*, this bushing being brought up before the bolts are tightened so that it receives the end of the taper hub *B* in the center of the work. The turret is held in place in this position while the bolts are being tightened. A simple type of face plate *D* is used for this fixture. Additional support

is given to the work by means of a spring bushing *G* having three points which come in contact with the work opposite to the center hub. This bushing is allowed to spring into place, after which it is held by means of the screw and plug at *J*. This work is a rough casting on which no previous machining work has been done, yet the fixture is so much out of the ordinary that it was thought best to include it here.

Work which has been threaded on the outside and on which other operations are to be performed in concentricity with the

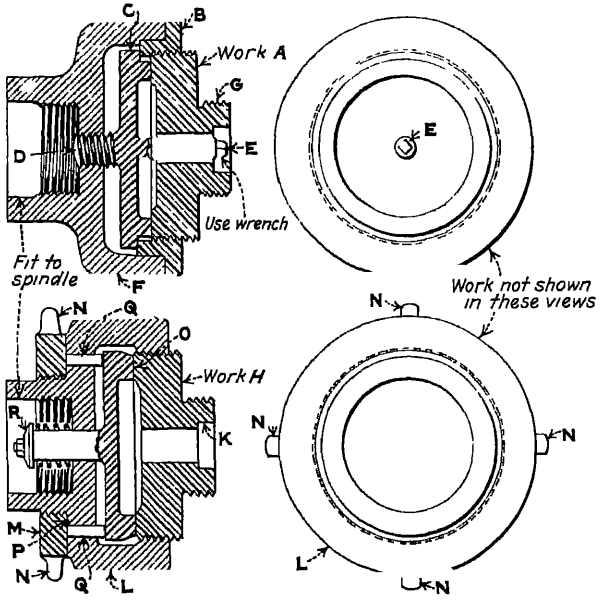


FIG. 55.—Outside-holding devices for threaded work

thread must be carefully held in a special fixture if work is to be done with precision and speed. It may be thought that the only provision necessary for work of this kind would be to screw the piece into a threaded bushing, letting it bear up against a shoulder of some sort, according to the nature of the work. This method might be all right in some cases if only a few pieces were to be machined, but it should be remembered that the pressure of the cut would naturally tend to tighten the work in the bushing, so that it might be very difficult to remove after the operation. Provision should, therefore, be made against this tendency by designing a special holding device.

An example of this sort is shown in Fig. 55 at *A*. The work shown here has been threaded on the outside of the large end and has been faced on one side and the center hole drilled. The work to be accomplished is the threading of the small hub *G* and facing the end. The threaded portion *G* must be concentric with the large end. A special nosepiece *F* is fitted with a hardened bushing *B*, which is threaded on the inside. The nosepiece is fitted to the end of the spindle. A flanged plug *C* is turned down at *D* and threaded with a left-handed, coarse-pitch thread. The flanged portion of this piece strikes against the inside end of the bushing *B*. When the work is screwed into the bushing it seats against a portion of the flanged member, as indicated. This acts as an end stop for the work. After the machining has been done, a socket wrench is applied to the end at *E* so that the pressure on the work is relieved, thus permitting it to be readily unscrewed.

Another type of chuck for the same piece of work is shown in the same illustration. The work *H* is screwed into a nosepiece *L*, so that it rests against a flanged member *O*. This member has two pins in it at *Q* extending through to the back of the chuck and bearing against the knock-off ring *M*. When the work is being placed in position, this knock-off ring is screwed up against the back face of the chuck at *P*, thus positioning the locating flange. After the work has been machined, the lugs *N* are struck a sharp blow with a lead hammer, which releases the work and allows it to be unscrewed from the chuck. The flanged member is provided with a stem on the end of which a nut and washer at *R* holds the coil spring in such a position that it keeps pressure against the knock-off member. The member *M* is threaded with a coarse-pitch, left-hand thread, in order to facilitate loosening it and also to make the movement more rapid.

Either of the two designs used in this illustration can be used for work of this kind, but in all probability the latter will be found more adaptable for the general run of work. It is important in any device into which a threaded piece is to be screwed to make sure that the end position of the work is positive.

Outside Holding Device.—Another example of an outside holding device for a threaded member is shown in Fig. 56. The work *A* is a flanged member which has been threaded on the hub as shown. It is to be machined on portions *B* and *C* in this operation. A nosepiece *D* is screwed to the end of the spindle and is

fitted with a threaded ring E. Two screws pass through this ring and enter a disk F, into which is screwed a draw rod G extending through to the rear end of the spindle and connected to the collet mechanism. When the work is placed in position in the bushing E it is screwed up against the hardened disk H, which gives it the end location. After the work has been done

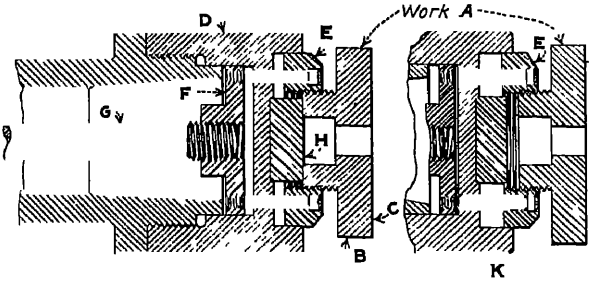


FIG. 56.—Outside-holding device for threaded flange

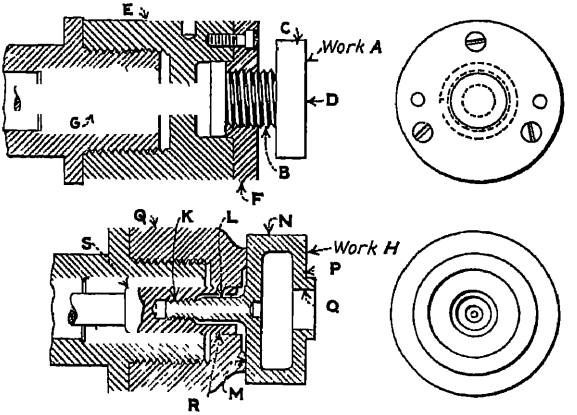


FIG. 57.—Two special chucks for threaded work

on the piece, a movement of the collet closing lever carries the bushing E forward, as indicated at K. This action removes all the strains on the work and allows it to be unscrewed very readily. It would be possible to use a device of this sort on a lathe not equipped with collet mechanism, by using a handwheel at the end of the spindle to operate the rod G. For small parts which have been threaded, a device of this kind can be used to advantages.

Chucks for Threaded Work.—In Fig. 57 are shown two other examples of chucks designed for holding threaded work. The

piece shown at A has been threaded at B, and is to be machined in this operation at C and D, so that it will be square with the threaded portion. The nosepiece E is fitted with a hardened threaded ring F, into which the work is screwed until it rests against the end of the plunger G that acts as an end stop. This plunger can be operated by a handwheel or by means of the collet mechanism, depending upon conditions. This particular design is so simple that it needs no further description, the working of it being very apparent from the illustration.

A piece of work shown at H has been threaded at K, turned at L and faced at M in a previous operation. The outside portion N, the hole O and the face P are all to be machined square and concentric with the threaded portion. The nosepiece Q is of hardened steel ground at R to fit the sleeve S. When the work is placed in position in the chuck, it is screwed into the member S, which is operated by a handwheel at the end of the spindle.

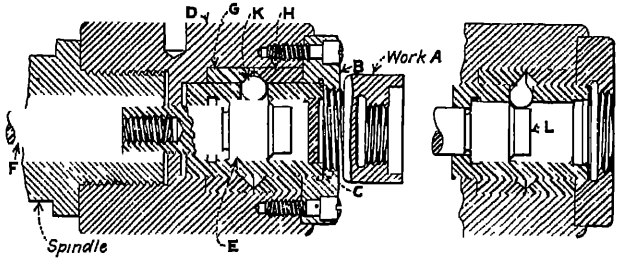


FIG. 58 —Quick-operating threaded chuck.

Considerable pressure is necessary in order to make sure that the work will not slip when the outside N is being turned. The method of releasing the work is obvious.

Quick-Operating Threaded Chuck.—In Fig. 58 is shown a design of a quick-operating chuck for holding threaded work. The piece A is screwed in to a hardened threaded ring B, and its endwise location determined by its contact with the end of the sleeve C. This sleeve is contained in a nose-piece D screwed to the end of the spindle, and it is operated by means of the shouldered member E attached to the operating rod F. The inside of the nosepiece is fitted with two hardened bushings G and H, chamfered where they come together so that they form an angular internal groove. The sleeve C has a hole in it slightly larger than the ball K, so that the latter will work freely in it. In

operating the device, the rod *F* is pulled back until the shoulder of the member *E* strikes the end of the inside of the bushing *C*, at which time the rod takes the position shown at *L* in the other detail. The ball is constrained to travel toward the center on account of its contact with the angular groove. This releases the whole mechanism and allows the work to be removed easily.

The advantage of an arrangement of this sort is in the positive lock which is provided for the bushing *C*, so that it is not necessary to keep a strain on any of the members. The ball secures the bushing in an accurate and positive manner, giving it at the same time correct end location.

CHAPTER V

INSIDE HOLDING METHODS

STRAIGHT AND TAPER ARBORS—EQUALIZING COLLARS, WASHERS AND DRIVING DOGS—PLAIN AND QUICK OPERATING THREADED ARBORS—EXPANDING ARBORS—DESIGN OF TAPER, SPLIT-RING AND EXPANDING PIN ARBORS

Work which is to be held from the inside, locating either on a rough surface or by means of one which has been finished previously, often requires some form of arbor to hold it properly. A large proportion of work of this kind is held on a slightly tapering arbor by means of friction. Other pieces are of such a nature that some kind of a driver can be used either in a hole or slot or against some irregular portion of the work. Provision for driving is an important factor in the design of arbors, whether they are of the plain or expanding types. There are a number of types of arbors used in general manufacturing; a few of them are of the standard form, yet many classes of work require special forms according to the shape of the work or the general requirements of holding.

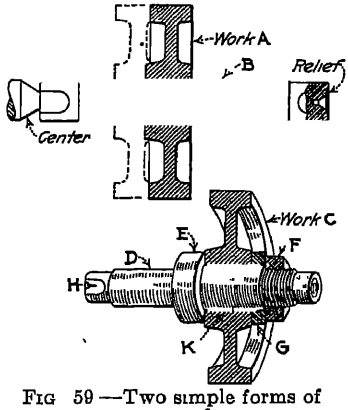


FIG 59.—Two simple forms of arbors

In Fig. 59 are shown two of the simplest forms of arbors. The work *A* is shown in position on a standard type of arbor *B*, designed to be held between centers on an engine lathe. The work is held in place entirely by friction. The common method of assembling the arbor and the work is to place the latter on an arbor press, and force the arbor into it under pressure. A taper of approximately 0.006 in. per foot is usually given to arbors of this sort. It will, therefore, be seen that the work might take the position shown or it might be as indicated by the dotted lines,

depending upon the amount of pressure used when assembling the arbor in the hole.

For this reason, such arbors are somewhat objectionable in general manufacturing when a number of pieces of the same sort are to be made, because the tool setting must be different for each piece on account of the various positions it may take on the arbor. For many kinds of tool work or single-part manufacturing, arbors of this kind are very useful. As only one piece is being made at a time no difficulty is caused by the position of the work on the arbor.

If a number of pieces of the same sort are to be made, as in the example *C*, a plain arbor like that shown at *D* can be made up with a collar or shoulder at *E*. Against this shoulder the work can be firmly drawn up by means of a nut *F* and washer *G* as indicated. One end of the arbor is flattened at *H* to receive the "dog" which is used for driving. Arbors of this kind are made cylindrical at the part *K* which fits the work.

The material from which arbors are made differs in various factories, both machine steel carbonized and hardened, and tool steel being used. A machine-steel arbor, carbonized, hardened and ground, will give good results on a great variety of work. Cast-iron arbors are sometimes used when work is of large size and for special cases when only one or two pieces are to be machined. Satisfactory results can be obtained on this kind of an arbor; but if very heavy cutting is to be done, it is advisable to reinforce the centers in each end of the arbor by means of hardened steel plugs. In designing arbors which are to be used on centers, care must be taken to make the latter as generous as possible and to lap them out carefully after the hardening and before grinding, in order that there may be no firescale or dirt in the centers which might cause them to beground in accurately.

A very useful form of arbor, which can be employed in cases where a number of small pieces are to be turned, is shown in Fig. 60. The end *A* is fitted to the taper in the spindle of the machine to which it is to be applied. The arbor is turned up with a shoulder at *B*, against which the work *C* is clamped by means of a nut *D* and washer *E*. In this example the arbor is relieved slightly at *F* to permit grinding up to the shoulder. This relief, however, tends to weaken the arbor, so that it may break at this point under excessive strain. A remedy for this condition is shown in the example *G*, in which a fillet is made at *H* in order

to give strength. A collar *K* is then used between the shoulder and the work, the collar being chamfered so that it will bear directly against the shoulder on the arbor. This makes a better form than the one previously described, as it is much more rigid and will stand greater abuse. Arbors of the kind shown here can be held in the spindle by means of a draw rod *L*, which is threaded into the end of the tapered portion *M*. The other end of this draw rod is threaded to receive a nut and washer, as shown at *O*. This method allows the arbor to be drawn back firmly into the taper on the machine.

The various points brought up in connection with design should

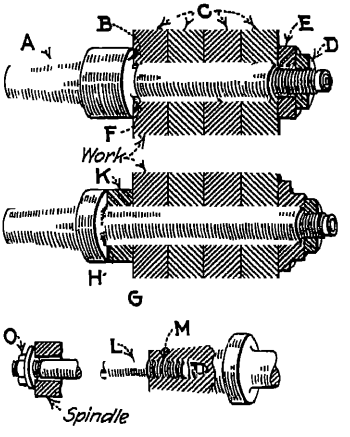


FIG. 60.—Plain arbors with tapered ends.

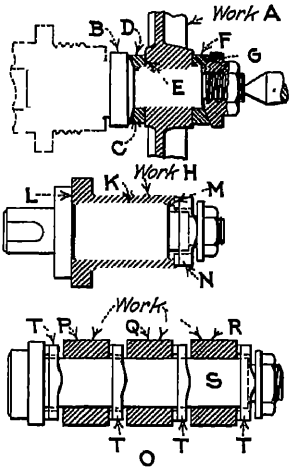


FIG. 61.—Arbors with equalizing collars.

not be passed over by the designer as unimportant, as they are the result of long experience. It frequently happens in the drafting room that a designer, unfamiliar with this class of work, is called upon to design something on this order. The general design resulting is frequently all right, but refinements of the principle, which a more experienced man would incorporate in the design, are left out by the less experienced draftsman.

Work which has been bored and reamed may not have been faced on both sides of the hub, as in the example *A* in Fig. 61. In holding work of this sort on an arbor care must be taken not to clamp it against the rough surface unless suitable provision is made so that no distortion will result. The matter can be

easily taken care of by using an arbor like that shown at *B*, having a shoulder *C* in spherical form. Against this shoulder a collar *D* rests, and the other side of the collar bears against the rough portion *E*. This side of the washer should be cut out so that it strikes against three points only. Another washer of similar form is used at *F*, in connection with a special nut having a spherical face *G*. By using this method, it is possible to clamp the work firmly and yet not distort the arbor by bringing unequal pressure to bear on the work.

Another example, showing a piece of work *H* which has been reamed at *K* and faced at *L*, has not been machined on the small end at *M*, this portion being left rough. In holding this

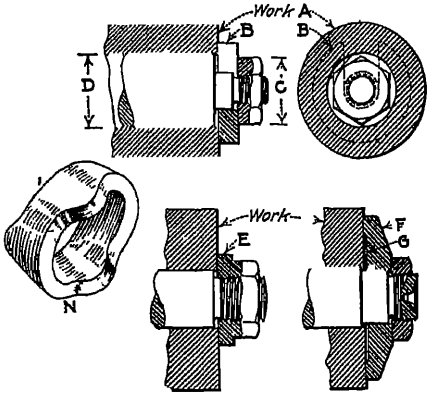


FIG. 62.—Use of washers.

piece of work, therefore, it will be necessary to put an equalizing washer *N* against the end of the work, in order that it may not be distorted. A detail of this washer is shown separately, and has some advantages over the other style shown because it does not require a special nut. It is perhaps a trifle more difficult to make up than the other form, but there is not enough difference to be of great importance.

An application of a similar principle is shown at *O* in the same illustration. In this case, there are three pieces of work *P*, *Q* and *R* which are to be held at the same time on an arbor *S*. None of these pieces have been faced on the sides, so that it becomes necessary to provide a number of equalizing collars, as shown at *T*. The design of this form of arbor will be readily understood from the illustration.

It is tiresome to unscrew a nut completely from a threaded member in order to remove the washer which perhaps is used to hold the work in position, as in the example *A* in Fig. 62. This trouble can be easily avoided by the use of a C-washer, such as that shown at *B*. It must be remembered that when this design is used the nut dimension must be considered across the corners, as shown at *C*. This should always be considerably less than

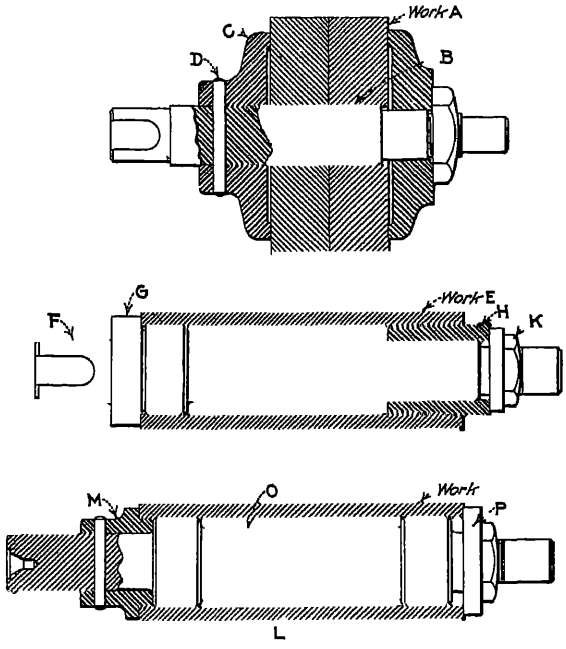


FIG 63 —Several forms of straight arbors

the diameter of the hole *D*, as otherwise there would be no object in using the C-washer and it would be necessary to unscrew the nut completely before the work could be removed. This point is occasionally overlooked in designing, and the distance across the flats of the nut is considered, instead of the dimension across the corners. Care must be taken in this regard when using C-washers.

Another point along the same general line is that it is not good policy to screw up a nut against the face of a piece of work, as shown at *E*, without using a washer between the nut and the work If this is not done, work will be marred by the sharp corners or

edges of the nut while screwing it up. Small washers are to be avoided, unless the work is such as to make their use necessary. It is generally better to make up a form something like that shown at *F*, and relieve the washer at *G* so that it bears only on the outer edges, as shown. This is much better construction than if a small washer were to be used.

Fig. 63 shows two pieces of work at *A* which are to be held on an arbor *B*. It would be expensive to make up this kind of an arbor with a shouldered portion at *C* as a part of the arbor. It is much better to make *C* in the form of a collar and pin it to the arbor with a straight or tapered pin, as at *D*. The hardening of the arbor must be considered when using this construction, as it might be difficult to drill and ream the pin hole unless the method of manufacture were to be carefully thought out. As it is shown here, there would undoubtedly be great difficulty in making it, yet by using an arbor of machine steel, carbonized and hardened, it is possible to allow an extra amount of stock at the point where the collar fits and turn this off after carbonizing and before hardening, thus leaving this part of the arbor soft enough so that it can be drilled without difficulty. A similar process can be used on the collar itself, so as to leave the portion through which the pin goes soft enough to be drilled.

Another method of holding a long sleeve is shown at *E*. This may be considered as a good example of what not to do. The arbor *F* itself has a shoulder at *G* against which work is clamped as indicated. The other end of the work is located by means of a bushing *H* having a slight taper on the outside. This bushing is forced into the end of the work by means of the nut and washer at *K*. There is no doubt about this method of holding, as there is sufficient friction developed to drive the work without difficulty. However, in attempting to disassemble the piece and remove it from the arbor, trouble will undoubtedly be experienced on account of the wedging action set up by the taper bushing inside the work. This could be avoided to some extent by making the bushing so that it would have a rather abrupt taper, in which case it would not stick in the work. Generally speaking, however, this method is not to be recommended.

Another form of straight arbor is shown at *L*, which is a simple type of plain arbor having a collar *M* pinned to it at one end to act as a stop for the work. The arbor itself is relieved at *O* so that it does not bear along the inside of the work. This makes it much

easier to place the work in position on and remove it from the arbor. The work is held in place by a nut and C-washer at *P*.

In order to avoid the necessity for placing the work on an arbor by means of pressure from an arbor press and to assist in making the operation more rapid, several forms of arbors have been devised which have automatic locking arrangements in their construction. Several examples are shown in Fig. 64. In one case, the arbor *A* has a shoulder at *B*, against which the work *C* rests. A slot *D* is cut lengthwise on the arbor to receive a roller *E*. This roller is turned down on each end to form pins, one of

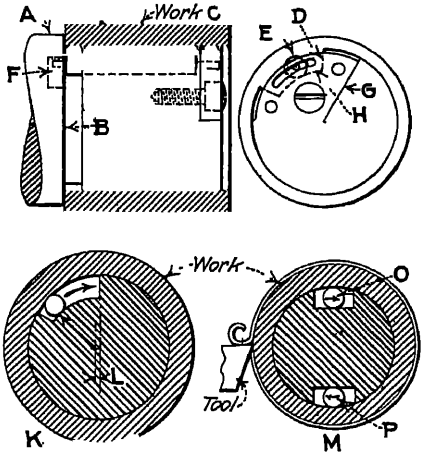


FIG. 64.—Arbors with dogs for driving.

which enters a slot in the shoulder of the arbor at *F*, while the other enters a slot in a retaining plate *G* fastened to the end of the arbor. The curved portion or bottom of the slot *H* is slightly eccentric to the center of the work, so that when the piece is placed in position and pressure applied in cutting it, the roll becomes further away from the center of the mandrel and grips the inside of the work more and more strongly, according to the pressure applied. The principle is illustrated quite clearly in the detail at *K*. The amount of eccentricity *L* does not need to be great, as too large an amount would prevent the roll from gripping the work firmly and there would not be a wedging action.

Another method which gives quite similar results is shown in an end view at *M*. In this case there are two rolls *O* and *P* opposite to each other in straight slots. The cutting action

tends to make them roll to the sides of the slots; and as they do so they become further away from the center, thus locking the work securely.

In Fig. 65 are shown several methods of making arbors for large-diameter work. The example *A* can be held in several different ways. The special arbor *B* is provided with a driver at *C*, and is intended to be held on centers in an engine lathe. By using a plug *D* in the faceplate, a "dog" is unnecessary. The

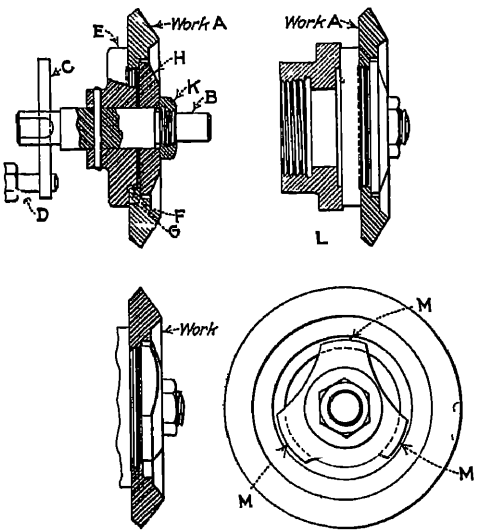


FIG 65.—Arbors for large work.

arbor is provided with a collar *E*, pinned to it and so arranged that the work locates directly on the shoulder *F* and against the face *G*. It is drawn up in place by a large washer *H* and a nut *K*. This form of arbor can be mounted on an adapter, as shown at *L*, if the nature of the work requires it. The method of locating the work is, however, the same in either case, the only difference being in the application of the arbor to the adapter.

A point of importance in connection with the use of large arbors is the bearing of the washer on the work. If made so that it has a contact all around, any slight inaccuracies on the face against which it is clamped are likely to throw the arbor out of truth. It is much better, therefore, to give the washer a three-point bearing, as indicated at *M*. If it is made a loose fit on the

stud, it will equalize any imperfections in the work to an extent sufficient to avoid trouble.

Work having a taper hole is often held on an arbor of some sort, and there are certain points which must be considered carefully in the design. The point has been brought out previously that it is difficult to ream a tapered hole so that the taper will bear an exact relation to the surface of the hub. On this account it is not

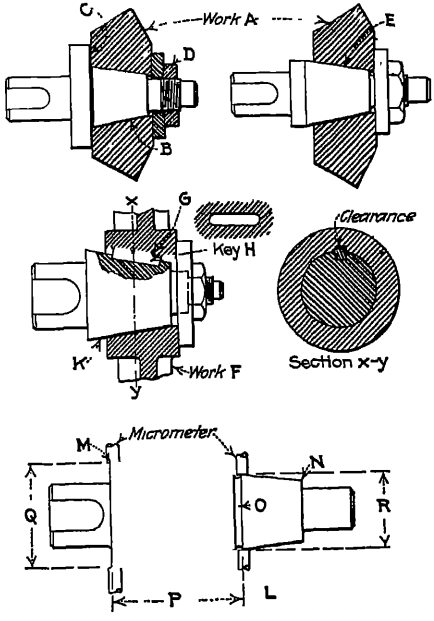


FIG. 66 —Taper arbors.

usually possible to locate a piece of tapered work on the taper and at the same time against the face.

An example which illustrates this point very clearly is shown in Fig. 66 in the work *A*, which is located on a taper arbor *B* and at the same time against the shoulder *C*. It is drawn back on the taper by means of a nut and washer, as indicated at *D*. It looks very nice in the drawing; but in reality it would not be advisable to use an arbor of this kind, as the work might "make" on the taper *B* before it reached the shoulder *C*, or it might strike the shoulder *C* before the taper completely filled the hole. In one case the shoulder would be of no use, and in the other case the work would not be located centrally because it would not fit on

the taper. By making up an arbor for this work like that shown at *E* all trouble is avoided, and the piece is located entirely by the taper, as it should be.

If a condition should be found such that it became necessary to locate by the taper and also against the shoulder, as might be the case with a piece of work having a wide flange which needed support, compensation could be made for the variation by using a taper spring bushing similar to one which has been previously shown. The necessity for such an arrangement on small work is comparatively rare. The work shown at *F* has a keyway cut in it at *G*. It is, therefore, a very good idea to take advantage of this fact in making up the arbor, and provide it with a key, as

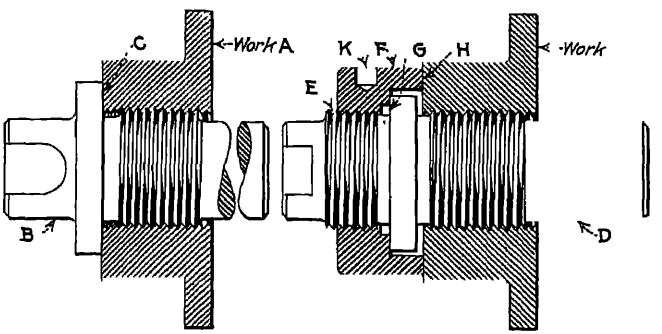


FIG. 67.—Plain threaded arbors.

indicated at *H*. The arbor itself *K* is of similar form to that shown at *E*. The advantage of providing an arbor with a key is that it serves as the means of driving the work, so that it is not necessary to use great pressure in tightening it on the arbor.

A point of importance in the making up of taper arbors is indicated in the diagram at *L*. The toolmaker who makes up the arbor is obliged to measure it with micrometers in order to determine the taper. It is easy enough to measure across the corners, as at *M*, but it is practically impossible to measure the diameter at *N*. If an arbor is made up, however, like that shown, giving a slight relief to the portion *O* and giving the dimension on the arbor between the arrows at *P*, the toolmaker can readily measure these portions and the taper can be determined by giving dimensions *Q* and *R*. The total length of the arbor can also be given to the point *N*, but the diameter at this point should not be

mentioned. A little care on the part of the designer will assist the toolmaker greatly on work of this character.

We have previously discussed the holding of threaded work when an outside method of locating is necessary. There are many examples, however, when the inside of a piece of work is threaded and the location must be taken from this for some other operations on the piece. Many of the principles which apply to the outside method of holding are also of importance in connection with arbors for threaded work. The simplest form of threaded arbor, but one which is not to be recommended, is shown at *B* in Fig. 67. The work *A* screws onto a plain threaded portion of the arbor and brings up against the shoulder at *C*.

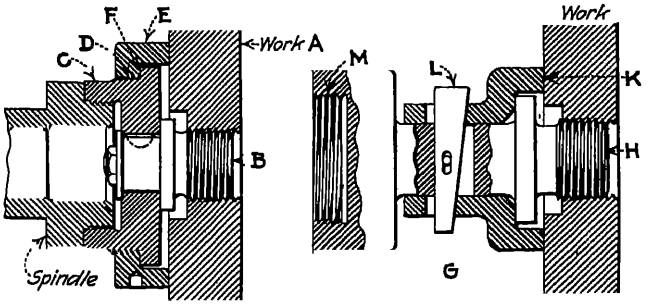


FIG. 68 —Two types of arbors for threaded work.

The pressure of the cut sets up a wedging action between the work and this shoulder, so that it is very difficult to remove the piece after it has been machined. An arbor like that shown at *D* can be designed, however, which will give excellent results. This type is threaded at *E* with a left-hand, coarse-pitch thread on which the collar *F* is mounted. This collar is screwed up against the shoulder at *G*, thus forming an end stop for the work which screws against the portion *H*. Pin holes are provided in the collar at *K*, so that after the work has been machined the collar can be easily loosened and the work removed without trouble.

Fig. 68 shows a piece of work *A* which is screwed onto a threaded plug *B* located in a nosepiece *C* on the spindle of an engine lathe. In its general principles, this arbor is quite similar to that previously described, but the work is somewhat larger and the arbor is applied directly to the spindle, instead of being held between centers as in the other example. The portion *D* is threaded with a left-hand, coarse-pitch thread on which a

collar *E* travels, until it brings up against the shoulder at *F*, thus forming the end stop for the work. The method of releasing the piece after it has been machined is obvious.

Another example which illustrates a poor method of holding the same piece of work is shown at *G*. In this example the arbor is threaded at *H* and the work screws onto it until it bears against the end of the sleeve *K*, which is held in its normal position by means of a wedge *L*. The arbor is arranged so that it screws on to the end of the spindle at *M*. The objection to this arbor is that the wedge will tend to distort the arbor, and the work will therefore not run true. In a very large and heavy arbor this trouble might not be caused, but for anything of small size there is such a force developed by the wedge that it cannot be relied upon for a purpose of this kind. It is better, therefore, to consider this design as another example of *what not to do*.

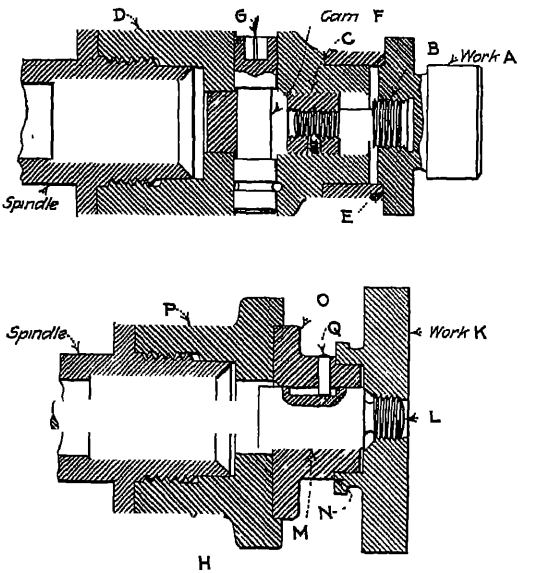


FIG 69.—Quick-operating threaded-work arbors.

Quick-Operating Threaded Arbors.—A very good example of a modern type of threaded arbor is shown in Fig. 69. The work *A* is screwed to the end of a threaded member *B*, which is fastened into a hardened and ground sleeve *C* fitting the inside of the nosepiece *D*. A hardened locating ring is provided at *E*,

against which a finished portion of the work is drawn. The operation of the device is by means of a cam cut at F and operated by a socket wrench in the hole G. This cam bears against the rear end of the sleeve which pulls back the threaded plug. The operation of the device is very rapid and positive in its action. Care must be taken not to make the cam too abrupt, as a slight eccentricity is all that is necessary. The various parts of this mechanism should be hardened and ground.

The example at H shows a piece of work K having a somewhat

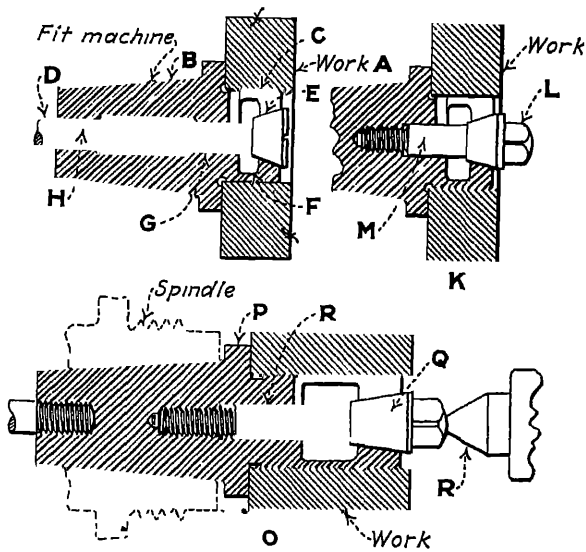


FIG. 70 —Arbors expanded by taper plugs

different method of location from those previously described. The work screws on to a threaded plug L, which has a cylindrical portion fitted into the collar at M. End location is determined by the shoulder at N. The collar O is fitted to the nosepiece P, and carefully ground when in position so that the hole is perfectly concentric. The rod L extends back to the rear end of the spindle, and is operated from this point by the collet mechanism. The pin Q simply keeps the rod from turning, a slot being provided in the latter to permit end movement. A device of this type is very satisfactory and can be quickly operated.

Considerable care should always be taken when several parts are assembled on a faceplate or nosepiece to make sure that they

are ground carefully, so that they will be perfectly concentric. The only way in which this can be done and be sure of the results, is to grind the parts in position on the machine on which they are to be used.

A common form of expanding arbor is illustrated in Fig. 70 the work *A* being held on the cylindrical portion of the arbor *B*, the taper end of which fits the spindle of the machine. The cylindrical portion *C* is split with saw cuts in three or more places so that it can be expanded on the end to hold the work. In the example shown, the expansion is done by means of a pull-back rod *D*, which has a taper end *E* fitting the taper portion of the arbor. In order to make it spring properly, the end is relieved by a recess as shown at *F*. This type of arbor really expands only on the extreme end; and, although for a great variety of work this action is sufficient to hold the piece, there is considerable likelihood of its running out of true after it has been in use for a while. This trouble can be avoided to some extent by a construction similar to that shown, in which the plug that centers the jaws and expands them has bearings at *G* and *H* which tend to keep it true. If the plug is true, the arbor itself will be accurate.

Another method of expanding the same general type of arbor is shown at *K*. In this case the arbor and expanding plug are self-contained, and the plug is tightened by means of a wrench at *L*. When this type of arbor is designed care must be taken to make the cylindrical bearing *M* long enough, so that it will assist in keeping the plug true and central. It is usually necessary to make the threaded portion a rather free fit, in order that there may be no cramp in the operation.

The two arbors mentioned are both designed to be used in the spindle of the machine, but it sometimes is necessary to provide an additional support, particularly when work is a little longer than normal. The example at *O* illustrates a method which can be used in cases of this kind. The arbor *P* is very similar to those previously shown. The plug *Q* is quite long and has a long bearing at *R* in the arbor itself. The end of the plug, which is squared up to receive a wrench, is so made that it has a countersunk hole in it to receive the center *R*. The extra support provided by this center enables the operator to take heavier cuts on the work.

In Fig. 71 are shown several illustrations of special arbors of the expanding type. The work shown at *A* illustrates a principle in arbors of this kind which is all right; but its application to the work shown is very bad indeed, on account of the lack of support which the work and the end of the arbor receive. It might be possible to use this same arbor with a center support and obtain good results from it, but its application as it is shown is not to

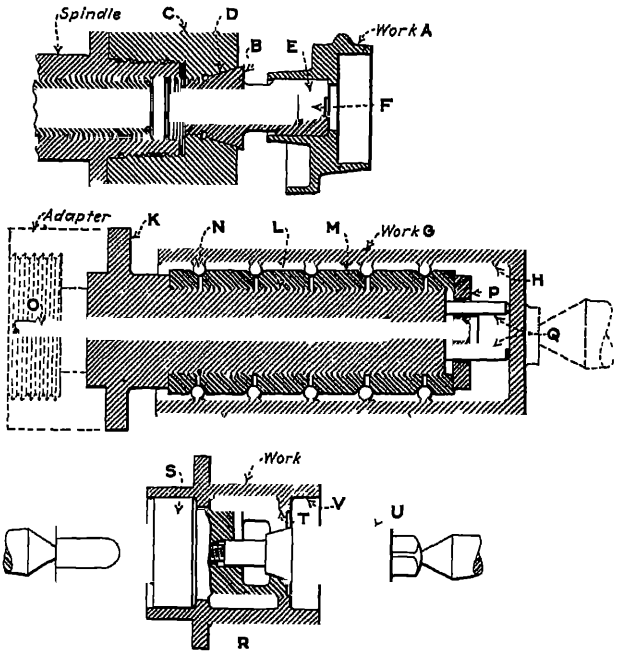


FIG. 71.—Several varieties of special expanding arbors.

be recommended. Several points in the construction are worthy of note. The arbor *B* screws into the nosepiece *C* and fits a tapered portion *D*, which centers it accurately. The end of the arbor is split in three places at *E*, and is expanded by means of a taper plug *F* operated by the collet mechanism on the machine. The general construction of the arbor and the method of operation are excellent.

An unusual type of expanding arbor is shown in holding the work *G*, which is a long shell of metal that has been rough-bored on the inside surface *H*. It is to be finished on the outside and the end in this operation. The body of the arbor *K* fits and is

fastened to an adapter shown by the dotted lines. This arbor is ground on the outside L and fitted with a series of hardened rings M, which are chamfered to receive the hardened and tempered spring rings N. The operation of the device is by means of the rod O which pulls back on the collar P, thus tending to force the spring rings out against the inside of the casting, and gripping it securely. The rod O is operated by the collet mechanism. In order to locate the work properly two stop pins are provided at Q. It is necessary to support the outer end of the work by means of a center point, as shown by the dotted lines.

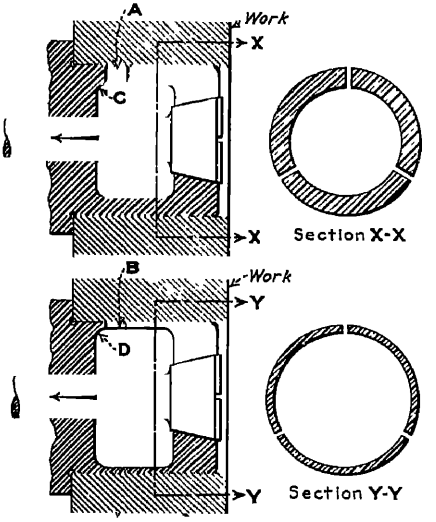


FIG. 72.—Design of split spring-arbors.

Another example of an expanding arbor is shown at R, the work in this instance being a hub which has been previously bored at S and finished at this end of the casting. The work locates on the portion S, and the other end of the arbor is arranged so that it will expand and grip the inside of the portion T. The plug used is similar to one shown previously, but it is so arranged that shell tools can be piloted on the portion U for machining the inside surface V. A center is used to support the end of the arbor.

The designing of split spring-arbors must be done with care, particularly as regards the proportioning of the material about the parts which are to be expanded. In order to bring out the

principles involved, two exaggerated examples are shown in Fig. 72. In one of these the section through *X–X* is too heavy, while in the other example the section through *Y–Y* is too light. In considering the matter, it must be remembered that the closer the design approaches a hinge construction the more successful the arbor will be, yet at the same time this matter must not be carried to extremes as in the case *Y*, because an extremely thin section might be cracked and ruined in hardening. There must

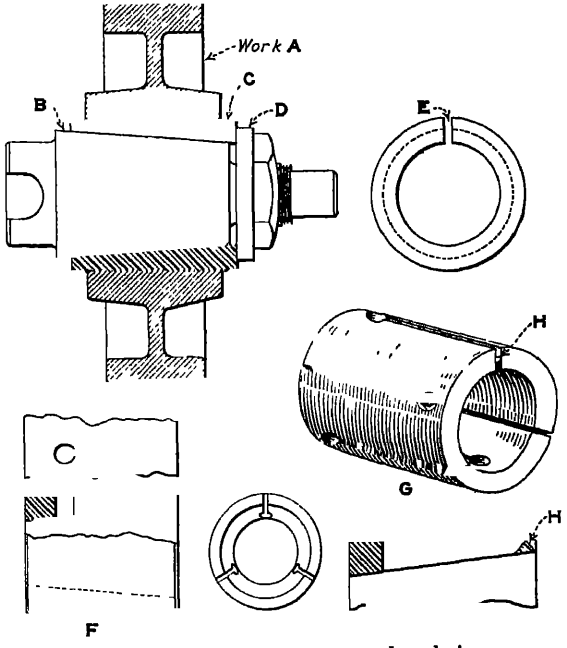


FIG. 73 —Use of split rings in arbor design.

be metal enough to withstand the heat and sudden cooling when the arbor is hardened and tempered.

It is customary to drill some fairly large holes at the end of the slot, as indicated at *A* and *B*, to assist in permitting spring to the jaws. Care must be taken also to avoid sharp corners around the hinged point, as they would be likely to cause cracks in hardening or fracture in use. Large fillets like that shown at *C* and *D* are a decided advantage in the design. Extra precautions should be taken in regard to these points if a successful arbor is to be made.

Many varieties of arbors depend for their success upon the expansion of a loose split ring. Fig. 73 illustrates several points in connection with the design of split rings for arbors of this kind. The work shown at *A* is held on a tapered arbor *B* by means of a ring *C*, which is drawn back on to the taper by means of the nut and washer at *D*. This particular ring is cut only in one place at *E*. As a consequence, the expansion is not even and untrue work will probably result from its use. This is probably the cheapest form of expansion arbor which can be made in

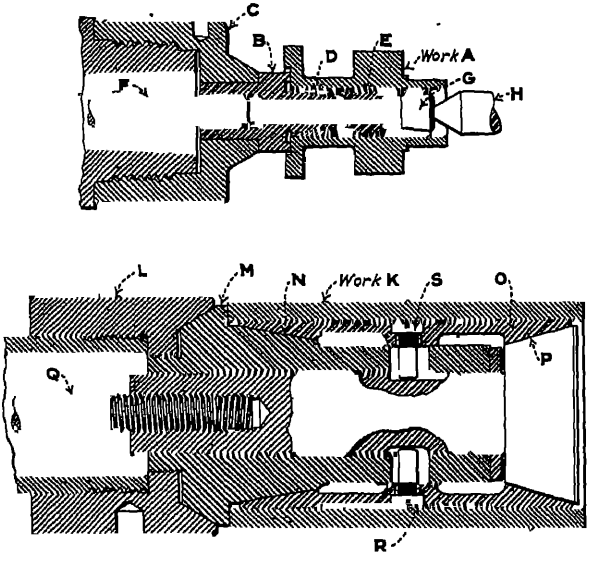


FIG. 74.—Two special arbors with expanding split rings

using a split ring. It is not recommended, however, because the entire principle of it is incorrect.

Referring to the illustration at *F*, another ring is shown which is split in three places, all of which splits are from one end of the ring. If an attempt were made to use this ring on an arbor such as that shown at *B*, it would not expand at all because one end of the ring is solid. If, however, the end of the arbor were to be relieved a trifle so that the bushing would not bear at this point, there would be a certain amount of expansion, but it would be all at one end of the bushing. The proper way to make a split ring is like that shown at *G*, where the ring is cut by three slots

from each end, which permits it to expand equally all over. In making up a ring of this sort the toolmaker commonly leaves a "tie" of metal at the end of each slot, as indicated at *H*. This "tie" is left in during all the operations on the work. After grinding, however, a thin wheel is used to cut it out, thus permitting the ring to expand. This method assists greatly in the various operations, as the work is not so difficult to hold true. Fig. 74 shows two very good examples of arbors in which the split-ring principle is used. The work *A* locates against a shoulder on the piece *B*, which in held in the nosepiece *C*. The ring *D* is split at both ends in three places with saw-cuts running nearly up to the center of the bushing *E*. A draw rod *F* runs through the center of the arbor and is provided with a taper end at *G*, which is supported by the center shown at *H*. In operation, the draw rod is pulled back, thus expanding the ring at *G* and at the same time pulling it back until it rides on the taper at *D*, which causes this end to expand, thus gripping the work firmly at both ends. In the design of an arbor of this sort, care must be taken to make the taper on *G* slightly larger than that at *D*, in order that sufficient pulling action will be exerted in addition to the expanding, so that the end *D* will be carried back and expanded.

A somewhat similar arrangement is shown for the work *K*, which arbor, however, is of much heavier construction than the other. The nosepiece *L* is fitted with a sleeve *M* having a taper at *N*. The bushing *O* is made in similar form to that previously mentioned, and it is expanded by means of a tapered plug *P* which is drawn back by means of the rod *Q*. In this case also the taper *P* should be more obtuse than that at *N*, in order to provide equal expansion on both ends of the bushing. The screws *R* and *S* simply act as retainers to hold the bushing in place.

Expanding Arbors.—In Fig. 75 are shown two arbors of special design and used for long work. In one example, the work *A* is located on a hardened ring *B* at one end of the arbor, a stop being provided for the inside of the work at *C*. The other end of the arbor is tapered at *D*, and at this end a spring expanding ring *E* is located. This ring is split in three places and has a spring wire ring *F* to hold it together. The other end of the bushing has a shoulder on it, as indicated at *G*. A threaded collar *H* is provided with a supplementary ring *K*, which grips the

shoulder at G and pulls the split ring back over the taper portion of the arbor, thus expanding it until it grips the inside of the work. A fiber disk is interposed between the shoulder of the collet and the sleeve K. To assist in placing the work on the arbor a tapered ring is provided at L. One end of the arbor at M is held on centers and "dogged." The other end receives its support from the work itself which has a countersunk portion N, in which the tailstock center is placed.

Another arbor for long work is shown at O. This example consists of a center member P tapered at Q to fit the inside of the sleeve R. The other end of this sleeve has a tapered portion S,

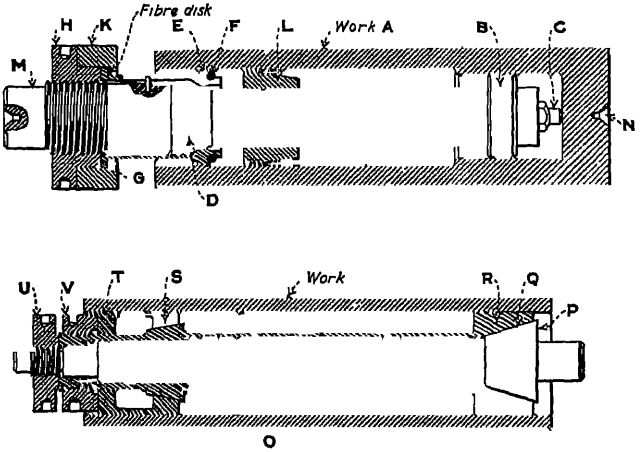


FIG. 75.—Two special expanding arbors

on which a spring sleeve T is located. The nuts at U and V are used to expand the two sleeves T and R. This design can be considerably improved by simply threading the end of the arbor P and carrying the nut U over in such a way that it would bear against the end of the bushing T. If this were done, one screw would be sufficient to tighten both members, and the equalizing action would doubtless be better than in the construction shown

The use of compressed air as a medium for operating expanding arbors on chucks has a number of advantages, as the amount of pressure can be easily controlled and equalizing action determined with certainty. Many of the devices previously illustrated can be operated by means of compressed air if desired. The application is simple, and the installation can be easily made to conform

to the conditions. Fig. 76 shows an expanding arbor intended to be operated by compressed air. The work *A* rests against the hardened ring *B* on the nosepiece *C*. There are eight pins *D*, four of which are at one end and four at the other end of the arbor. These pins are held in position against the taper sleeves at *E* and *F* by means of coil springs. The sleeve *F* is attached to

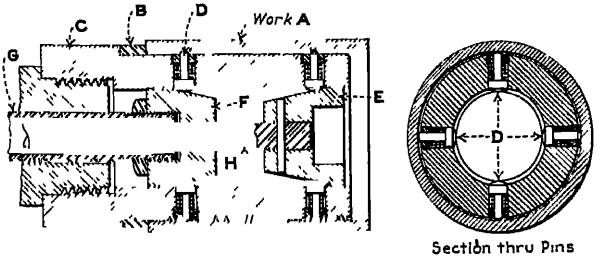


FIG. 76.—Air-operated expanding arbor.

the member *G*, which is hollow. The other taper piece *E* is operated by the bar *H*, which passes back through the spindle and is fitted with a piston against which the air operates. The sleeve *G* also has a piston, and between these two pistons the air pressure is exerted. As the air is turned on, the sleeve *F* moves forward and the sleeve *E* backward, the action being nicely equalized by

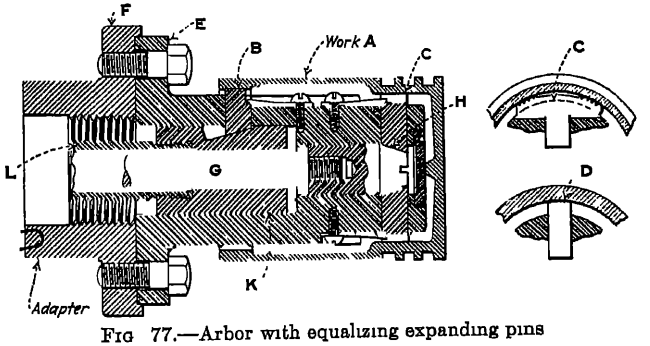


FIG. 77.—Arbor with equalizing expanding pins

the pressure of the air. The releasing of the arbor is easily accomplished by a reversal of the motions mentioned. A device of this kind can be operated mechanically if desired, by means of a right- and left-hand thread and a suitable handwheel at the end of the spindle The principle shown here can be applied to many kinds of work, both rough and finished.

Another type of arbor having a series of equalizing expanding pins, and frequently used for the holding of automobile pistons is shown in Fig. 77. This chuck can be operated either by means of air or by a handwheel at the rear of the machine. The work *A* is held by means of three pins *B* at one end, while at the other end two pins are used, both of which may be like that shown at *C*. If the construction of the piston is such that there is very little room at this end, it is even possible to use pins like those shown at *D*. Another arrangement can also be made by using three pins at the forward end of the piston, and placing two of these pins at a suitable angle, as determined by the amount of space available.

The body of the arbor *E* is fitted to an adapter *F* to which it is bolted, as shown. A rod *G* extends through the spindle of the machine and is used to operate the angular member *H*, which controls the movement of the forward pins. A bushing *K* controls the movement of the pins *B*, the operation being accomplished by its connection with the sleeve *L*. If the rod extends

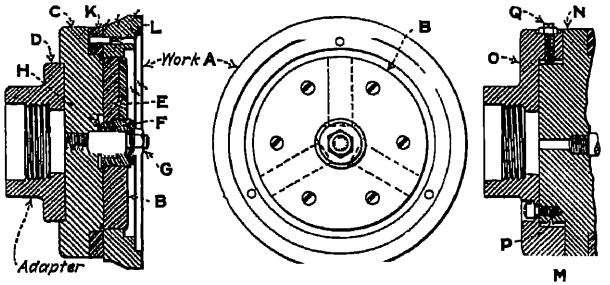


FIG. 78.—Expanding arbor with provision for truing-up.

through the spindle and is shouldered at the other end, and if the sleeve *L* is threaded so that it fits the inside of a handwheel, a few revolutions of the latter will serve to expand and contract the pins readily. There is a very good equalizing action when operated in this way, so that the pins at the front and rear of the piston bear with a uniform pressure.

Truing-Up Device.—When a piece of large diameter is to be held accurately by an inside finished surface, a device can be used like that shown in Fig. 78. The work *A* locates approximately on the outside diameter of the hardened member *B*, which is fastened to the faceplate *C*, the latter being screwed to an

adapter *D*. The member *B* is slotted in three places to receive special hardened jaws *E*. These jaws are expanded and contracted by the movement of the bushing *F*, which is controlled by tightening or loosening the nut and washer at *G*. A coil spring at *H* assists in releasing the bushing when the nut is loosened. The work locates, in addition to the points mentioned, against the hardened ring *K*, which is provided with a driving pin at *L* that enters a previously drilled hole in the ring being machined. By using this driver much less pressure is required to hold the piece firmly on the arbor. The various surfaces which are to be machined in the operation are shown by the *f* marks.

For very accurate work, it may be found a decided advantage to arrange arbors of this or other kinds in such a way that they can be trued up from time to time, if they should become slightly inaccurate. A method of making provision for this contingency is shown at *M*. The faceplate *N* is mounted on the adapter *O*, and held back by means of several screws *P*. It is also centered on the faceplate by other screws *Q* around the outside of the adapter. When it is necessary to true up the device, all these screws can be slightly loosened and adjustments made, so that the important points will run absolutely true. After testing with an indicator and making sure of the truth of the arbor, the various screws can be tightened, and the arbor is ready for work.

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CHAPTER VI

TURNING TOOLS FOR TURRET LATHES

FACTORS TO BE CONSIDERED IN DESIGNING TOOLS—USE OF BACK RESTS—CONSTRUCTION OF TOOL HOLDERS—ARRANGEMENT OF CUTTING TOOLS—BOX, UNIVERSAL AND OTHERHEAD TOOLS—METHOD OF HOLDING TOOLS—ADVANTAGES OF PILOTING FOR RIGIDITY AND ALIGNMENT

In all kinds of production work, the machine furnishes the power and applies it in various ways. The tools, however, do the actual work, removing the metal and finishing the surfaces as determined by the "set-up." Any machine without tools is of little use in the production of metal parts. If the tool equipment is not well designed and proportioned for the work it has to do, the machines cannot be operated at maximum efficiency, and as a consequence the production will suffer. To obtain high production, the tool equipment must be intelligently designed, carefully built and properly used.

Many factors affect the design of tools for turret lathes—the material to be cut, the method of holding, the amount of stock to be removed, the length and width of the various cuts and the accuracy required. Many of the points cannot be covered fully in general notes, but will be treated in detail in connection with the specific examples illustrated.

(1) Material to be machined: In designing tools for any sort of cutting, the material which is to be cut naturally has an effect on the design. The shape of the work and its fragility are also important factors. The cutting requires tools which are properly ground for the kind of material, and shaped to remove the metal in the easiest possible way. Very thin work influences the design because the cutting action may so tend to distort the work that a support of some sort is necessary, either for the tools or for the work itself. Material may be of such a nature that it is cut dry, or again it may require cutting lubricant in order to produce good results. These points must all be taken into consideration in the design.

(2) Method of holding: The method by which work is held affects the design of tools in two ways. First, by the possibility of interferences which might be caused by a lug or clamp on some portion of the fixture; and second, by the direction of the cut. In machining irregular castings care must be taken in the design of tools, so that they cannot strike or interfere with portions of the fixture.

(3) Amount of stock to be removed: This is an important factor, not only with respect to the shape of the toolholder itself, but also on account of the necessity for sufficient rigidity to withstand the pressure of the cut. This factor affects the cutting tool itself, as there must be sufficient "section" to carry away the heat rapidly.

(4) Length and width of cut: When short work is to be machined, the cutting tools do not require a great deal of care in their design, other than to make sure that they are properly shaped and held. When the work is long, however, tools must be designed so that they have considerable overhang from the turret. This matter is likely to cause trouble either in the indexing of the turret or in vibration during the cut, unless some method of support is provided.

(5) Accuracy required: In turret-lathe work it is possible with careful tooling to produce work within very close limits of accuracy. Suitable provision must be made to compensate for slight inaccuracies in the indexing of the turret. Unless this is done, work may vary somewhat over or under the size desired.

Turret-lathe work usually consists of a number of different operations on the same piece of work. The operations are performed in sequence; and, for example, work may be turned, faced, drilled, bored, reamed, tapped, recessed or threaded. All of these operations require different tools, some of which are standard, some special, some applied to the turret and others to the cross-slide. We shall treat them separately as to design, but later shall consider them as they are affected by others which may be used with them. The operations of turning, drilling and boring are often performed together, and occasionally a grooving or facing operation takes place at the same time as one or more of the former operations. This depends upon the nature of the work and the method of handling.

Design of Turning Tools.—In the removal of stock from the outside of a piece of work by the process of turning, the presentation of the tool to the work is of great importance. It is not our

purpose to go into the theory of cutting tools to a great extent, but a few fundamental points which are important in connection with the design will be discussed briefly. The purpose of a cutting tool of any kind is to remove stock as easily and rapidly as possible, at the same time leaving the work in good condition. Modern machine tools are usually proportioned so that they have power enough to pull practically any kind of a tool combination through the work. Some of the heavier machines have excess power sufficient to break the largest tool that can be put in the holder without "stalling" the machine, or even causing it to hesitate. Maximum tool efficiency can only be attained by having a great number of tools working simultaneously, thus removing as much stock as possible in a minimum amount of time. Consideration must be given to the work itself, the method of holding, the accuracy required, and the cutting lubricant. Feeds and speeds must also be properly proportioned in accordance with the nature of the work.

Cutting tools for turret and engine lathe work really consist of two parts, the holder and the tool. The combination of holder and cutting tool are often referred to as a "tool," although this is not strictly accurate.

Two fundamental points in design are as follows:

(1) The holder must be so proportioned that it will be rigid in relation to the work. It must be firmly secured to the turret or cross-slide, and must support and hold the tool firmly.

(2) The tool must be large enough to carry away the heat generated by the cutting action, and so proportioned as to withstand the stresses to which it is subjected. Small tool sections are not economical in any way, except for light finishing cuts.

Tools for turning bar stock are arranged in two different ways, viz., radial or tangent to the work. The radial position is commonly used for box tools and multiple set-ups of various kinds. Tangent tools are used most frequently in universal turning tools or other similar devices. In the application of a cutting tool to the work, the aim is to remove the stock by a tool of such shape that the metal will be "sheared" rather than "torn" off.

Several examples which illustrate the application of a cutting tool to a piece of bar work are shown in Fig. 79. The illustration at *A* shows the position of the radial tool *E* with respect to the work. The form which the chip takes is clearly shown. At *B* the tool *F* is a tangent tool. Its shape is somewhat different from that

shown at E and it removes the metal in a little different way, there being more of a wedging or splitting action in the tangent tool.

The position, with respect to the center of the work, of radial tools for turning is important. If placed above the center, as shown at C, the tool G under the stress of a heavy cut may be deflected and take the position shown by the dotted lines. This tends to produce chatter, as the tool "digs into" the work when deflected. If the tool is set as shown in the example D, slightly below the center, a heavy cut may cause it to deflect as shown by the dotted lines at H. However, its position is such with respect to the center and the outside of the work that this deflection

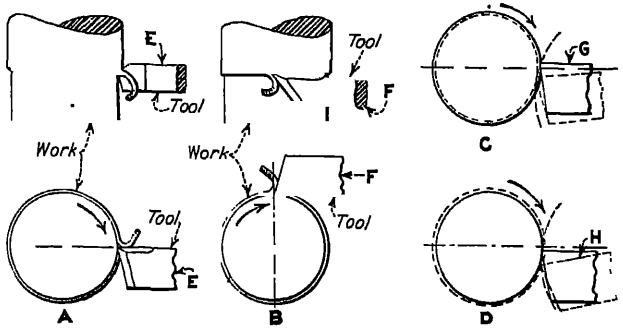


FIG. 79.—Application of tool to work.

tends to throw it away from the work and not into it, as in the preceding case. Both of these examples apply entirely to outside turning, and they are somewhat exaggerated in order to illustrate the points clearly. It is an advantage at times to position the tool slightly below center on a heavy cut, in order to avoid the chatter that might otherwise be caused.

Back Rests for Bar Work.—If the work being turned tends to spring away from the tool, the result will be inaccurate work and a certain amount of chatter. In order to provide against such a condition, box tools are so designed that the work is supported by means of back rests so arranged that the work lies in a sort of a V. Several examples which illustrate the use of back rests are shown in Fig. 80. In the example A, the work is being cut by means of the tool B, and opposite to it are two rollers C and D, adjustably mounted so that they give support to the work during the cutting action. This example shows the use of back rests in connection

with a radial cutting tool. Another example shows a tangent tool at *E* and two roller back rests at *F* and *G*. The latter are in a somewhat different position with respect to the tool than those shown in the previous example.

In cutting bar stock with box tools having roller back rests, the rests may be adjusted differently according to the work. If the cutting is being done on a rough bar of stock like that shown at *X*, tool *H* would be set slightly in advance of the rollers *K*, so that the latter would bear against the finished surface. It is possible when machining cold-rolled steel, like that shown at *Y*,

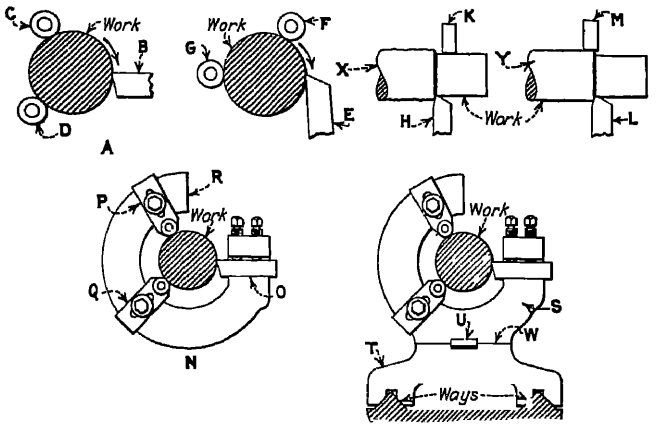


FIG 80.—Use of back rests.

to adjust the rollers slightly ahead of the tool *L*, as indicated at *M*. The fact that the stock which is being cut is smooth allows this arrangement to be made.

In order to give a little better idea of the general features of importance in a box tool, another example, which illustrates several points in connection with the design, is shown at *N*. This type of tool uses two adjustable slides at *P* and *Q*, each of which is so arranged that it can be reversed to bring the rollers ahead of the tool, or *vice versa*. The tool itself is clamped in place at *O*, and a large body of metal is under it, so that it has sufficient support. It is necessary to provide a wide opening at *R* in order to allow the chips to pass out freely, so that they will not clog up or pack in around the tool itself and interfere with its proper working.

On work requiring very heavy cutting, it is sometimes necessary to support the box tool. Provision for a condition of this kind can be made by the use of a casting, such as that shown at *T*, which is applied to the ways of the machine and clamped in position. The box tool *S* is furnished with a tongue at *U*, to act as a guide in the member *T* and assist in taking the pressure of the cut. The surfaces at *W* are carefully finished, so that the tool *S* slides freely over the lower member. Very often when a support of this kind is to be made, hardened blocks are provided on the bottom of the tool and on the top of the member *T*. This is simply a detail of the construction regarding which the tool designer will decide according to the nature of the work.

Design of Turning Tools.—There is nothing much simpler in design than a turning tool used in a turret lathe for a small diameter. At the same time there are some points of interest which should not be neglected by the tool engineer when attempting to design tools of this nature. There is great difference between a tool which will work, and another which will work at maximum efficiency. Almost any kind of a holder with setscrews which can be used to hold a tool will turn a piece of work approximately to a given diameter, if it is set properly. Approximate sizes, however, are not good enough for the majority of work, and the results obtained from properly designed tooling are much more satisfactory than those produced by tools which are poorly designed.

There are a number of well-designed, standard, single-point turning tools on the market that can be purchased cheaply and used for work within their capacity. Certain pieces of work require special tools, either on account of their length or diameter, and the tools must then be designed to suit the conditions. It may be mentioned here that it is always advisable to design a special tool in such a way that it is more or less adjustable, so that it can be used if certain small changes should be made in the work. In other words, the tool should have a certain amount of latitude, so that it can be adapted to other work in case of need.

In Fig. 81 are shown several types of simple turning tools for comparatively small work and short lengths. The work shown at *A* is a plain cylindrical piece that is to be turned by the tool *B*. The machine on which the work is to be done is of the round-turret type, which permits holding the tool by the shank *C* only. A binder of some sort is generally used on the turret to make it secure. The body of the tool is of cast iron enlarged slightly at *D*

and made rectangular in shape there in order to hold the tool. The tool E is of rectangular section, so that it fits an angular slot in the end of the holder. It is held in place by two setscrews, as indicated at F. The section which holds the tool should be made heavy enough to give plenty of stock for the setscrews, so that the tool can be clamped rigidly. If the operation to be done is a finishing cut, or if the amount of stock to be removed is not great, a tool of this type will give satisfactory results. The body of the tool should be made substantially so that it will not spring and cause chatter on the work.

A similar type of tool is shown at G, the work being the same

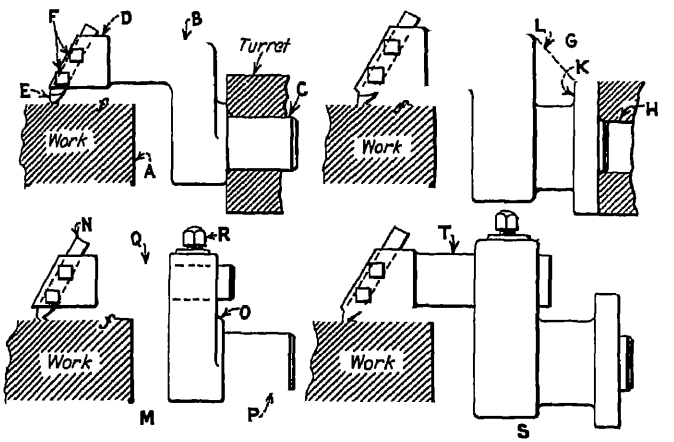


FIG. 81.—Simple turning tools for turret lathes.

as in the preceding case. A different type of turret is used here, and the hole H simply assists in locating the tool on the face of the turret. Bolts are used to secure it through the flange K. This design would be improved by reinforcing with one or more ribs, as shown by the dotted line at L. In general the type shown here will permit of slightly heavier cuts than the style at B, because of the added support that the turret gives and the somewhat stronger construction throughout.

It is very convenient to make a turning tool so that it can be adjusted both for length and diameter. This can be done as shown at M, in which the tool N is held in a bar which is adjustable lengthwise in the holder O. The holder is clamped in place in the turret by means of the shank P. The bar Q is flattened on its upper side to prevent it from turning, and can be clamped

in any desired position by means of the setscrew at *R*. A similar type of holder applied to another kind of a machine is shown at *S*. The general features of this holder are like those previously described, the bar *T* being adjustable, so that it can be moved longitudinally as may be required.

None of the tools shown in this illustration are suited for heavy cutting, as they are not intended for this class of work. They

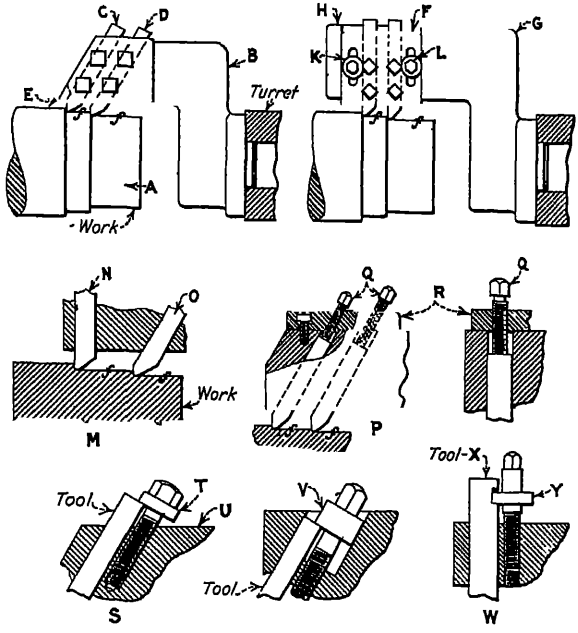


FIG 82.—Arrangement of turning tools and backing-up screws.

will give excellent results on work which does not require the removal of a great amount of stock, but care must be taken in the design to make all parts heavy enough to stand the pressure of the cut.

A few points have been mentioned in connection with the design of holders for turning tools, but very little has been said about the cutting tools themselves, as far as methods of holding and adjusting are concerned. Very frequently several tools are required to produce different diameters at the same setting. They can be located in the same holder; but it is necessary to make the holder proportionately stronger, as the pressure of

e cut is greater. Thus, a holder for a single tool can be much ghter in construction than one used for three or four tools ıtting together.

The work *A* shown in Fig. 82 is to be finished on two diameters, ; indicated by the finish marks. The tool holder *B* is of similar ype to those previously described, but it has two tools in it, ıown at *C* and *D*. These tools are spaced the correct distance ɔart, as determined by the shoulders on the work. They re held by means of setscrews in a slot in the end of the older. In general, this tool conforms to standard practice, but ıe end *E* should not project beyond the end of the tool, as this mits the adaptability of the tools so that it cannot be used to ırn work close to a large shoulder because of the interference t the point *E*. This trouble can be easily avoided, however, y cutting off the end of the block, as shown by the dotted line.

In setting two tools which are to be used to turn shoulder istances and diameters, it is not advisable to set both of them t an angle unless they are so arranged in the slot that they can e moved about. It is quite difficult to grind and set tools of his kind to produce accurate diameters and shoulder distances ıt the same time.

Another method of making up a tool block for the same piece ıf work is shown at *F*. The toolholder *G* is a casting similar to he one just described, but the block which holds the tool is ıdjustable vertically, so that several diameters can be handled.)ther blocks with different tool spacings can be used in the same ıolder. An objection to this design is that the end *H* extends ɔeyond the first one of the cutting tools. For special work this night not cause any trouble, but it would limit the field of action ɔf the tool if it were wanted for another piece of similar work. ;n making up a holder with an adjustable block, the latter must ɔe made very heavy, as the pull of the cut comes against the ɔlock. The two screws shown at *K* and *L* will not be sufficient ,o hold it. It would be an improvement to use four screws nstead of two. A still more rigid construction could be obtained ɔy placing the block on the other side of the holder *G*, thus let-;ing the pull of the cut come directly against the body of the ɔasting.

The diagram at *M* shows another method of arranging two tools for cutting diameters and shoulders on the same piece of work, one of these tools *N* being set straight, while the other *O*

is at an angle. It would be better to arrange the tools in the opposite way, and use the angular tool at *N* and a straight tool at *O*. This method would allow the tool to work close to a shoulder, if necessary.

Wherever possible, it is good practice to use a backing-up screw behind the tool, as shown in the example at *P*. The two screws at *Q* are supported by a plate *R* fastened to the top of the holder. The tools can be adjusted for diameter by means of

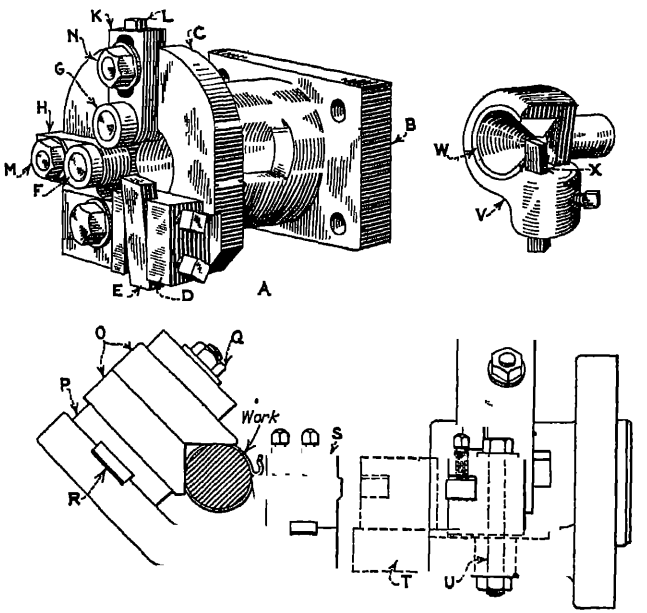


FIG 83 —Box-tool designs

the backing-up screws, which greatly assist also in preserving diameters on the work, as they form fixed stops against which the ends of the tools rest.

Another method of adjusting a tool is shown at *S*. This method is limited in its action, as the collar on the screw at *T* will interfere with the casting at *U* after the tool has been ground several times. It is better to arrange the screw as shown at *V*, by counterboring the casting so as to permit a greater amount of movement. Another method for the same purpose is shown at *W*. The tool *X* must be made specially when this kind of an

adjustment is used, as the collar *Y* fits a groove in the tool itself. For certain kinds of work this arrangement may be found advantageous, because it permits adjustment both in and out.

In making up box tools for turning bar stock, care must be taken to avoid too much depth below the center of the turret hole. All turret tools must be indexed with the turret, and they are likely to strike the back of the turret slide if made too deep. The tool must be made adjustable, and the back rests should be so designed that they can be used either ahead or behind the cutter. A very good type of box tool is shown at *A* in Fig. 83. The portion *B* is made so that it can be fastened to the turret and suitably located in the turret hole. The overhanging portion *C* is fitted with a toolblock *D*, in which a tangent tool *E* is placed. The tool can be adjusted to the required diameter by moving the block *D*. The rollers *F* and *G* are mounted on adjustable blocks *H* and *K*. They are provided with screws at *L* for adjustment and can be locked in place by the nuts at *M* and *N*. This is a clean-cut design, with plenty of provision for chips, so that they are not likely to clog and tangle up on the tool.

When work is of small diameter, it is not always possible to use roller back rests, because they cannot be brought in very close to the center. A V-type of back rest like that shown at *O* can be used when such a condition is encountered. The two pieces are adjustable on the slide *P*, and are locked in place by means of the nut *Q*. In designing multiple box tools, this type of back rest is frequently used, because it takes less space than the roller type. Several blocks like that shown at *P* can be made up, and the back rests adjusted according to the requirements. They are located by means of a tongue *R* in the body of the holder. Toolblocks for multiple cutting can be made as shown at *S*, and several of them can be applied to one holder for cutting different diameters. The holder may be extended as shown by the dotted lines at *T* to accommodate several blocks.

If shoulders on the work are very close together, it may be necessary to place two or more tools in one block, and also to do away with the bolt *U* and provide a different method of fastening. This last may be accomplished by tapping into the block from the underside and using collar-head screws for holding. The designer of turret tools is not frequently called upon to design box tools, although there is an occasional demand for a tool to handle work which cannot be taken care of by the standard types. The infor-

mation given here should be sufficient to bring out the principal points in connection with the design.

Another type of tool used for bar work is shown at *V*. It is a pointing tool, used for chamfering the ends of bar stock preparatory to turning. The design is very simple and consists primarily of a casting with a shank fitting the turret of the machine. A hardened conical bushing *W* is cut away at one side to allow the tool *X* to act against the work. The bushing, being tapered, supports the work and centers it while the chamfer is being cut.

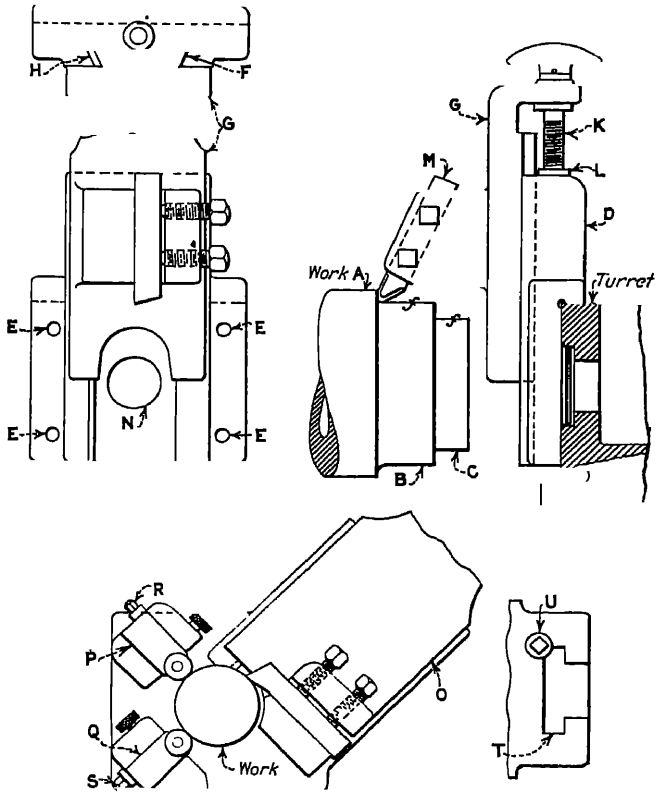


FIG. 84.—Universal turning tools.

Universal Turning Tools.—An adjustable tool suitable for turning cylindrical work is shown in Fig. 84. The work *A* is to be turned on the two diameters *B* and *C*. It is possible to design a tool to handle work of this kind so that it will be adjustable for

all diameters within its capacity. The tool holder, shown at *D*, is fastened to the turret of the machine by means of screws at *E*. It is machined with a dovetail as indicated at *F*, and a slide *G* is fitted to it. An adjustable gib is provided at *H* to take up wear. The slide is adjusted vertically by means of the screw *K*, which enters a hardened threaded bushing *L* in the body of the holder. The sliding member *G* has a tool *M* set at an angle of 30 deg., in order to allow working close to a shoulder.

A tool of this kind can be fitted with a graduated handwheel and a pointer, in order to permit of accurate adjustments. Combinations are occasionally made with a holder for drilling or boring, in connection with this tool. The holder can be placed in the hole *N*. If necessary, this portion of the body can be extended to form a rigid support. Tools of this general type can be fitted with a slide having a tangent tool for short cuts on bar work; but as the holder is not provided with back rests, it cannot be used for very heavy cutting.

By setting the slide at an angle, as indicated at *O*, space can be obtained for the two back rests, as shown at *P* and *Q*. These back rests are adjustable by means of screws at *R* and *S*. They can be designed so that either leading or following rolls can be used. A detail of the construction of the slide is shown at *T*. The screw *U* is utilized to adjust the blocks toward the center or away from it. In designing tools of this sort, rigidity is an important consideration, as any vibration in the tool will cause chatter in the work. The amount of space available affects the design very strongly, and the greatest care must be taken to keep the various parts within the space permitted, so that no interference will be caused in the indexing of the turret or by the position of other tools on adjacent turret faces.

Tools of the overhead variety can be given additional rigidity by extending them entirely across the turret, as indicated at *A* in Fig. 85. These tools are applied to the flat form of turret. Two heavy brackets are provided at *B* and *C*, and through these a double-end bar *D* is passed. This bar is cut in the center at *E*, and one end is piloted and held in place in the other bar by a screw *F*. The brackets *B* and *C* are fastened to the turret by the screws *G*, and location is obtained by the tongue *H*, which fits a slot in the turret. Each end of the bar is slotted for the tools *K* and *L*. Backing-up screws may be provided for the latter, if desired The amount of overhang at *M* is determined by the size of

the bar and the work which is to be done. It is advisable to make the overhanging ends of larger diameter than the rest of the bar, if heavy cutting is to be done. The tie across the turret makes a very substantial construction, and gives greater rigidity than when single tools are used. The diameters which can be cut with a bar of this kind are limited, on account of the vertical position of the tool. Work of smaller diameter than that shown can be turned if the tool does not extend too much below the bar.

When larger diameters are to be cut, an arrangement can be

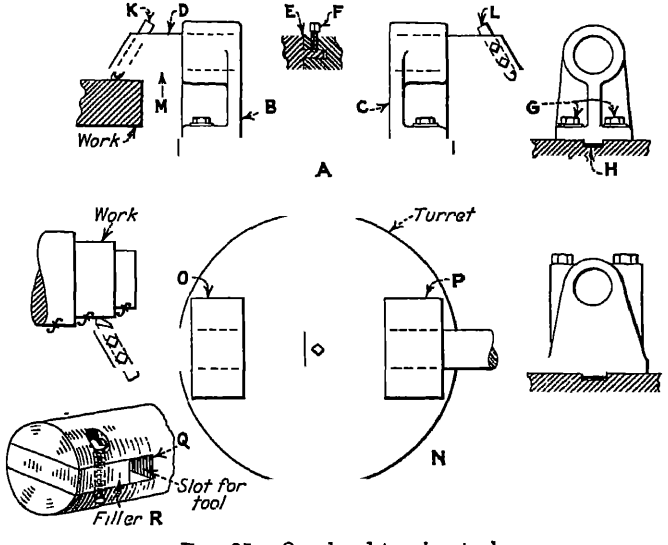


FIG. 85 —Overhead turning tools.

used like that shown at *N*. Two brackets *O* and *P* hold a bar of similar kind to that just described, but the work is machined from the side instead of overhead. Some turret lathes have an adjustable head, while others use an adjustment on the turret. In either case the diameters are obtained by an adjustment of the relation between the turret and the spindle. When using bars of this kind, the method of holding the tool is important. If the bar is slotted, as shown at *Q*, a filler block *R* can be used to stiffen the end of the bar and prevent it from springing open. This gives a rigid and economical construction.

Tools of rectangular section, which can be purchased in standard stock sizes, should be used wherever possible. The portion

of the tool which is not used for cutting should not usually be ground or finished in any way, but it should be held in the holder in the rough state. Consequently, slots for tools should be made from $\frac{1}{32}$ to $\frac{1}{16}$ in. larger than the specified size of tool which is to be used. In certain kinds of box tools for small work, tools are finished all over and carefully fitted to the holders; but on larger work this is seldom done, except in the case of a very complicated piece of work.

At *A* in Fig. 86 is illustrated another matter of importance.

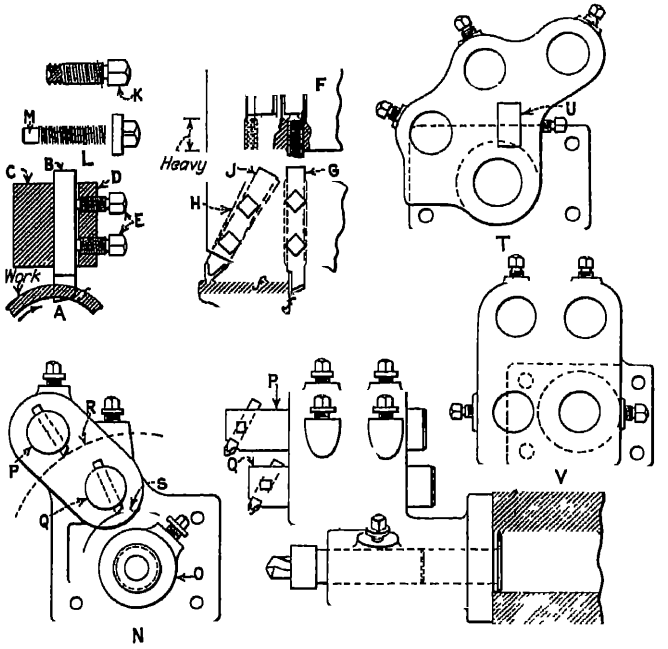


FIG. 86.—Methods of holding tools

The tool shown at *B* is held in an overhead turning tool made of cast iron. As the operator stands at the front of the machine, it is much more convenient for him to be able to make all adjustments from this position, than if he is obliged to walk around behind the machine for this purpose. Therefore, the setscrews *E* are conveniently placed at the front of the tool. This is not theoretically correct, because the thrust of the cut is in the direction indicated by the arrows, so that it must be taken by the setscrews instead of against the solid metal. This is a case where theory and practice do not coincide.

If the designer places the setscrews as shown, care must be taken to make the section *D* very heavy, so that there will be plenty of metal to absorb vibration. If made as shown, section *D* is too thin and section *C* much heavier than it needs to be. These conditions should be reversed, so that the appearance is more like that at *F*. The same thing applies to an adjustable toolblock which is mounted on a holder with tools arranged for the same kind of work. There is another point of importance in the method of holding tools. If they are made as indicated at *G* and *J*, it is wise to provide for a certain amount of play in the slot, as shown at *H*. This will permit tool *J* to be adjusted in a certain relation to tool *G*, even if there is considerable variation in the way each tool is ground. If both tools are fitted carefully to a slot, it is very difficult to set them for exact work unless they are ground to a gage.

A setscrew which is used to hold a tool in position appears to be a very simple matter, yet certain types have been found unsuitable. The cup-point screw, shown at *K*, is usually unsuitable for holding tools, because the cup point tends to make an impression in the tool. After the tool has once been ground, the setscrew will naturally find its way back to the original marks, thus making it very difficult to obtain a correct setting. The same thing applies to the use of a round-end screw, and neither of these types should be used in tool holders. In addition to these points, a setscrew having a head like that at *K* is not as convenient for the operator as a collar-head type of screw, because the wrench slips down over the head, thus causing delay and inconvenience. The ideal form of screw for holding tools is shown at *L*. It is a collar-head type with a flat relieved point *M*. There are certain cases where this type is objectionable on account of the collar, particularly when a number of screws are placed in a holder quite close together. In general, however, it is advisable to use it wherever possible.

The material from which screws are made has been the subject of considerable discussion, because the ordinary commercial screws often break under excessive use. The writers have found Hy-ten steel, suitably treated, to be admirably adapted for setscrews requiring severe service.

There are several forms of multiple tool holders which are capable of considerable adjustment, and can be used for quite a range of work. One of these is shown at *N*, this type being a

casting having a center boss O and two holes P and Q at different distances from the center. Tools can be inserted in all three of these places, so that diameters approximating those shown by the dotted lines at R and S can be easily machined. Variations in the shoulder distances can be taken care of by longitudinal adjustment of the bars P and Q. A drill or boring bar can be inserted in the hole at O.

Another multiple tool is shown at T. This holder is provided with one central hole and three others arranged at different distances from the center. A rectangular slot is also cut at U, so that facing or turning tools of rectangular section can be held according to requirements. Another simple holder having four holes is shown at V. Its general principles are similar to those of the other holders.

Any multiple holder which is to be used as a standard tool and subject to considerable variation in the class of work to be handled, must be rigidly designed and proportioned in such a way that it will be as adaptable as possible. The bars used in the holder can also be standardized, so that they can be used for turning and boring. Holders of this general type are often purchased from turret lathe manufacturers.

Advantages of Piloted Tools.—In order to obtain maximum production from turning or boring tools, they should be piloted so that all possibility of vibration is eliminated. Under these conditions only can high production be obtained, together with the essential degree of accuracy. In the piloting of turret tools two points are achieved, one of these being the additional rigidity obtained by the use of the pilot and the other the accuracy of alignment. It is not always possible to pilot a turning tool, due to some condition on the machine or the work.

In the example A shown in Fig. 87, the work B is to be turned by the tool C in a holder D on the face of the turret. In order to assist in aligning the tool, and to help in making it more rigid, a bushing E is placed in the chuck and the bar F is guided by it during the operation of turning. The bar can be furnished with a cutter for boring the hole. This method will give some additional stability to the tool; but, as its position is at the center of the work, it does not prevent sidewise vibration to any great extent.

A much better arrangement is shown at G, in which a smaller piece of work is being turned by the tool H in a holder K. The

latter is furnished with a pilot bar L which is guided in a bushing M, the latter being held in a special bracket N on the spindle cap of the machine. This arrangement gives the tool an excellent support at the point where it is needed, and at the same time assists in the alignment.

The same piece of work could be bored at the same time by arranging the holder so that the boring bar O could be used in it. This boring bar being piloted in the chuck, as shown at P, would give additional support to the holder and make a very substantial device. There are usually slight inaccuracies in the indexing of

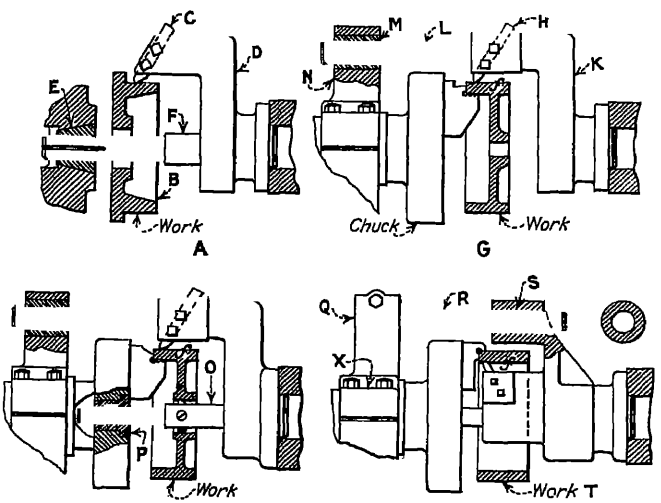


FIG. 87.—Examples of piloted tools.

the turret, and piloted tools assist greatly in correcting them, so that more accurate work can be produced in this way.

It may be objectionable for one reason or another to use a pilot on the turning tool itself. When this is the case, it is possible to use a bracket, as shown at Q, furnishing it with a pilot bar R, so arranged that it will enter a place provided for it in the holder at S The work T can be simultaneously turned and bored by a tool of this kind. The turning tool is not shown, as it lies in a different plane from that of the pilot bar. This method of piloting is not as good as the other, because the alignment of the bar is dependent upon the short bearing obtained by the bracket at X. It is useful, however, for cases where the regular piloted tool cannot be used.

The brackets which are used on the spindle cap to support the bar of a piloted turning tool must be designed according to the headstock arrangement of the machine. Sometimes it is not possible to place the bracket directly over the spindle, and it may be necessary to select some other place for it. Several varieties of brackets are shown in Fig. 88. The example at *A* is a plain, symmetrical casting *B*, which is fastened to the spindle cap by means of four bolts at *C*. The bracket is furnished with a bushing *D* in which the tool is piloted. Usually this design cannot be used, because it is directly over the spindle, which would normally

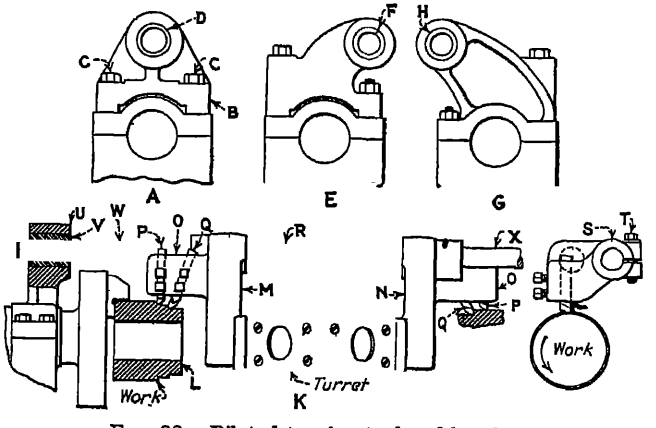


FIG. 88.—Piloted turning tool and brackets.

be in line with the position of the cutting tool. The pilot would more frequently be placed at the right- or left-hand side of the tool, as this would not require the bushing to be made so high above the spindle, and would allow greater latitude for the turning tools. When a pilot bracket is fastened to the spindle cap, the latter should be taken off and machined so that a good fit is obtained. It is advisable also to make sure that the cap is adjusted properly before doing any fitting of the bushing *D*. The bracket should be doweled in place in order to insure its proper alignment.

The example at *E* shows a pilot bracket having a bushing *F* at the right of the spindle and considerably above it. In the example *G* the bracket forms a unit with the spindle cap itself, being designed specially to replace it. The position of the bush-

ing *H* is at the left of the spindle in this example, and this is really the proper place for it to obtain the best results.

If we consider the cutting action of the tool, there is a slight lifting tendency, which is more or less counteracted by the pilot. There is at the same time a tendency to pull the tool toward the front of the machine, due to the direction of rotation of the work. As the bushing *F* is to the right of the spindle, the lifting action will not be counteracted to as great an extent in this case as in the example *H*, where the bushing is to the left. In the latter case, the pressure of the cut gives slightly more downward force.

A very good example of a rigid, piloted turning tool is shown at *K*. The work *L* has two shoulders which are to be machined with considerable accuracy, and a large amount of stock is to be removed. The turret is fitted with two brackets *M* and *N* on opposite sides. Each of these brackets has a heavy section of metal *O* which extends out from the face of the turret and carries the tools *P* and *Q*. A long tie bar *R* extends entirely across the turret and is fastened in each bracket. The pilots *W* and *X* pass through the bosses *S*, which are split so that the bars can be clamped in place by means of pinch binders at *T*. A bracket *U* on the spindle cap carries a bushing *V*, in which the bar is piloted. The construction is such that the two brackets *M* and *N* are tied together very rigidly, and the bar gives an excellent support for the turning tools. For large diameters, long work, and other pieces which require exceptional accuracy in machining, the use of piloted tools is indicated and will be found a decided advantage in increasing production and giving greater accuracy.

Several forms of piloted turning tools have been illustrated, and their application to various kinds of work described. The principles of design are fundamental, yet they serve to make the subject clear by their simplicity. In order to demonstrate the value of the data given, two examples of piloted tools of improved design are shown in Fig. 89. The large casting *A* is to be turned at *B* and grooved at *C* and *D*. The tools used are designed so that they can be adjusted to handle another piece of work of the same kind, but 2 in. smaller in diameter.

The casting is held by the outside of the flange in a three-jaw chuck with special jaws The turning-tool body *E* is of cast iron of substantial section, fitted and bolted to the turret face. The forward end of the tool body is provided with a heavy pilot bar *F*, which enters a bushing *G* in the bracket *H* on the spindle cap.

The cutting tool K is mounted in the rectangular steel block tongued at L, so that it fits a slot in the casting, which acts as a guide when adjusting the block vertically for different diameters. The screws at M are used to hold it firmly after setting. Fine adjustment of the tool K is obtained by means of a backing-up screw not shown.

The grooves at C and D are cut by two tools in the cross-slide

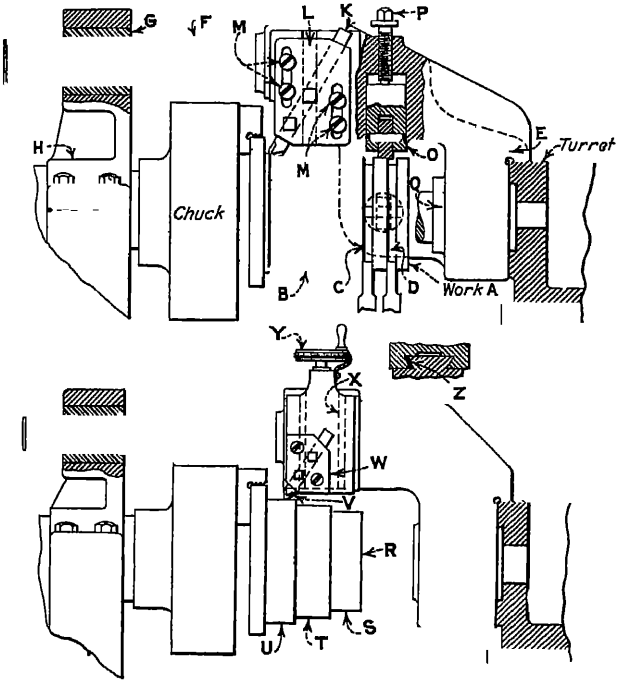


FIG 89.—Adjustable piloted turning tools.

toolblock. They are shown in the illustration 90 deg. from their actual position, in order to avoid complications in the drawing. In order to save time in the operation, the grooving tools are started before the turning is completed. Two roller supports are used to give stability to the work and steady it while grooving. One of the supports is shown at O, with an adjusting screw above it at P. The other is at the back of the work directly opposite the grooving tools, as shown only by the dotted lines.

This tool arrangement may be considered as a progressive design suitable for high production of accurate work. The

general outline of the tool is pleasing to the eye and free from sharp corners and projections. The operator's convenience has been considered in the provisions for accurate adjustments, and its stability is apparent even to the casual observer. In fact "it looks efficient" as it really is. Adaptability to other work has been considered in the design, as shown by the central boss *Q*, which is bored out so that it can be used to hold a boring bar or cutter head, if desired.

Another overhead tool is shown in position for turning the work *R*. The pilot bar, bracket and body of the tool are quite similar to the one used for casting *A*, and the body is fastened to the turret in the same manner. This tool is designed for turning several diameters like *S*, *T* and *U*, successively and with precision. The cutting tool *V* is mounted in a block *W*, which is fastened to the dovetailed slide *X*. The latter is controlled by a graduated handwheel *Y* by means of a screw. The slide is furnished with an adjustable taper gib *Z*, as indicated in the sectional detail. Readings for various diameters can be easily obtained from the graduations on the handwheel. This tool should not be considered strictly as a high-production type; but for work of the kind shown, which is routed through the factory in lots of 100 pieces at a time, it will be found a great time saver.

CHAPTER VII

BORING TOOLS

WORKING CONDITIONS—PRINCIPLES OF BORING—POSITION AND SHAPE OF TOOLS—METHODS OF FASTENING TOOLS IN HOLDERS—METHODS OF ADJUSTING CUTTERS—USE OF ROUND AND RECTANGULAR SECTION CUTTERS—PILOTED BARS—MULTIPLE BARS

True boring is a generating operation in which a single-point tool revolves about a center in alignment with the hole to be bored. In turret lathe work the tool does not revolve but the work does, which produces a similar effect. It it were possible to support both tool and work so that each were absolutely rigid and without spring, the hole produced would be perfectly true and of exact size as determined by the distance from the center to the cutting point of the boring tool. There is more or less spring to the tool and possibly a small amount in the work itself, so that bored sizes in production work are likely to vary a trifle, making it necessary to depend on a reamer for sizing the hole.

A point of importance in boring is the fact that a generated hole is true and concentric with the center of rotation of the work. A bored hole generated by a single-point tool is the first step in the accurate sizing of a concentric hole. A boring tool is often preceded by a twist drill, core drill, or cutter head, these being used to remove stock preparatory to the boring operation.

The method used in boring is determined to a great extent by the shape of the hole in its rough state. A number of conditions are encountered, and each may require a slightly different method in order to produce a hole which will be true and concentric. Fig. 90 illustrates a number of these conditions found in castings and forgings. The example *A* illustrates a short, straight cored hole of small diameter; *B* is a long straight cored hole. The holes *A* and *B* both extend entirely through the casting, but in the example *C* is a "blind" hole, which does not run entirely through.

The treatment in boring these three castings would be considerably different. In the first case *A* a short and rigid boring

tool could be used and good results obtained. In the case *B*, a much longer tool would be required, and several cuts would undoubtedly be necessary in order to produce an accurate hole.

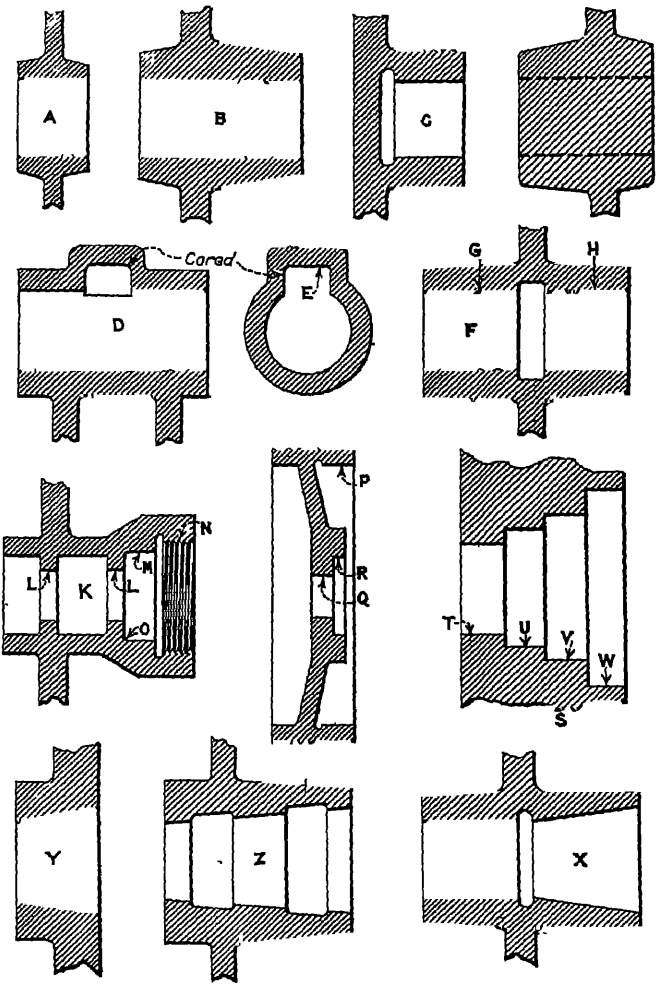


FIG. 90.—Examples of work requiring boring operations.

If the holes *A* and *B* are approximately 1 in. in diameter when finished, the cored hole would probably be about $^{13}/_{16}$ to $^{7}/_{8}$ in. in diameter. Therefore, it would be possible to use a boring bar

with a pilot which would give sufficient support to obviate excessive spring in the tool. If the hole is much smaller than the size mentioned, it would be difficult to use a piloted tool, hence the operation of boring would be slower and less accurate. In the case *C* the hole is "blind," so that no pilot can be used and the work must necessarily be produced by an unsupported tool.

In the example *D* the hole is cored and cylindrical, and there is a pocket at *E* on one side of the casting. This condition is frequently found where the boring operation is an interrupted cut. This intermittent pressure on the tool is severe, and both bar and tool should be made heavy enough to withstand the sudden strains.

In the example *F* there are two holes to be bored at *G* and *H*, and the difference in the finished diameters is only $\frac{1}{32}$ in. If this is a cored hole arranged to be bored with a boring bar having two cutters, the first cutter will have to bore the entire distance through the piece, as the difference in diameters is so slight. The second tool, which bores the diameter *H* will really be a finishing tool, as it will not be required to encounter the scale on the inside of the cored hole. The first tool, therefore, will naturally wear much faster than the second, and as its service is much more severe it should be proportioned accordingly.

In the example *K*, three diameters are to be bored at *L*, *M* and *N*, and the portion *O* must be finished to a large radius. A bar having multiple cutters would be needed for this work, but the mistake should not be made of using a "round-nose" tool for the roughing cut at *O*. Round-nose tools for boring cuts require considerably more power, as they come in contact with more surface and remove a wider chip.

The example shown at *P* is a large diameter which must be bored concentric with the hole *Q* and the recess *R*. Surfaces of this kind are usually handled by a boring bar in combination with a cutter head. The example *S* is a piece of work of large diameter having four shallow concentric holes, *T*, *U*, *V* and *W*. Holes of this variety can also be most conveniently handled by means of a combination of a bar and cutter head

The example *X* is a combination of a straight and a taper hole. There are two ways of machining work of this kind. The straight hole can be bored with a piloted bar, and the tapered portion roughed and finished by means of taper stepped reamers; or, both straight and taper holes can be bored with single-point tools, the

taper being generated by a special taper-boring tool. The example *Y* is a plain tapered hole, while that at *Z* is a tapered hole relieved by a cored portion as indicated. Tapered holes require special treatment, which will be taken up later.

Cored holes which are to be bored and reamed are seldom machined properly A cored hole will not usually run true if the

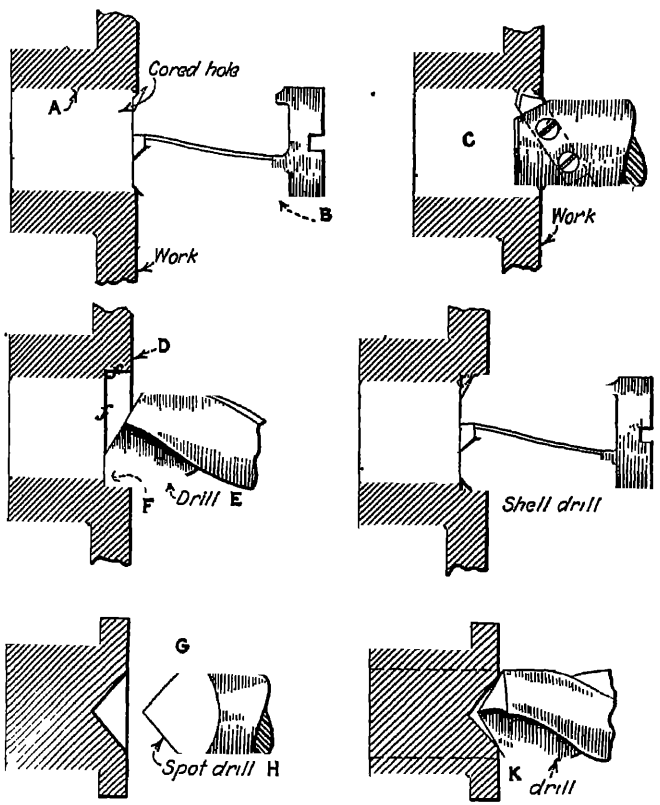


FIG 91 —Methods of boring a hole.

work is held by the outside diameter, unless it is indicated and trued up. When there is only one casting to be machined this method can be used, but in quantity production it is neither practical nor desirable.

In Fig. 91 is shown in diagrammatic form both correct and incorrect methods of generating a hole by means of boring. In

the example, the hole *A* is cored, and will therefore doubtless run out of true slightly when the work is set up on the machine. The core drill *B*, if used first, will naturally follow the cored hole and produce a finished hole which is eccentric to the center of rotation to some extent at least. If the next tool used is a boring tool *C*, it will naturally follow the previous hole, but will cut more on one side than on the other, thus tending to true up the hole. The result here will be a round hole slightly eccentric. In finishing the work by the use of a reamer, this tool will undoubtedly follow the bored hole, so that the completed work will be untrue and slightly eccentric. The amount of eccentricity will depend to a great extent upon how nearly the original cored hole runs true with the outside of the work. Many shops use this method and are, therefore, obliged to true up work after the operation.

Work done in this way is started incorrectly, and as a consequence the final hole is inaccurate. It is just as easy to do it right as it is to do it wrong, and a correct principle will lead to gratifying results. The correct method of sizing a hole of this sort is shown at *D*. The first tool *E* may be a short twist drill ground away for clearance and made square on one lip. The size of this drill should be a few thousands of an inch smaller than the core drill which is to be used. If the hole is generated a short distance so that it appears as shown at *F*, this portion will undoubtedly be true with the center of rotation of the work. The core drill, or shell drill, can then be used, and as it is started accurately, it will not be likely to run out of true to a great extent while passing through the work, and is not influenced greatly by the eccentricity of the core. By following this tool with a boring tool, the hole is trued up by a generating action, so that the final floating reamer will produce a true and concentric hole.

In the example *G* the work is a solid forging which is to be drilled, bored and reamed to size. Work of this kind should be spotted with a short, rigid spotting tool similar to that shown at *H*. This tool produces a true center in the work, so that it can be followed by a standard twist drill like that shown at *K*. The angle of the spotting drill should be slightly greater than that of the twist drill, so that the lips of the latter will start to cut first in the hole as shown in the example *L*. The drill will then start true, and the cutting will be much better. After the hole is drilled, it may be followed by a boring tool and reamer, as in the preceding example.

The shape and position of the boring tools are both important factors in the generation of a true hole. Fig. 92 shows a cored hole *A*, which is to be bored by the tool *B*. The hole is blind so that no pilot can be used, and the bar will therefore be more or less flexible, depending upon the size and depth of the hole. If the

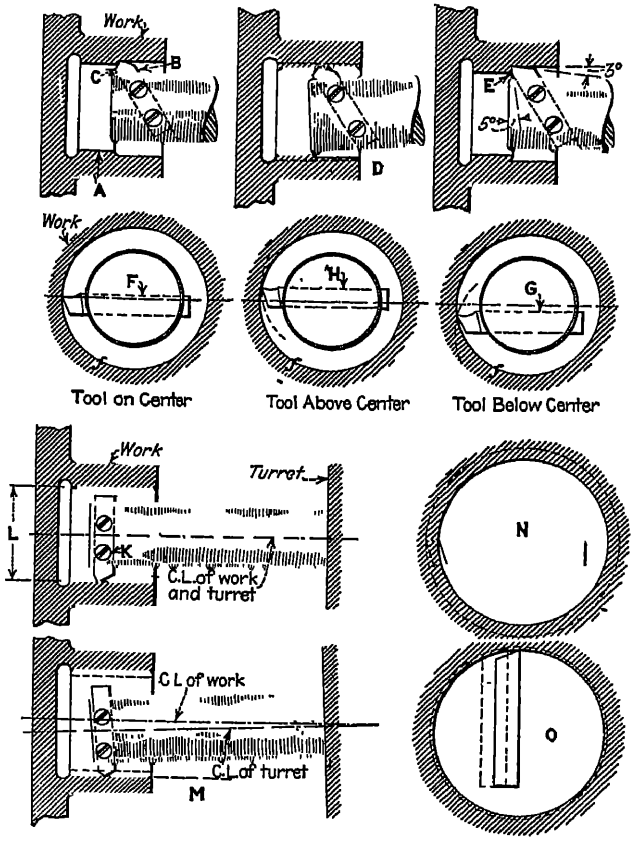


FIG. 92.—Tool positions in boring operations.

tool is made so that the nose or cutting point is shaped as shown at *C*, the flexibility of the bar and the angle of the tool will tend to make it deflect and to take a position as shown exaggerated at *D*. This action is caused by the tool not getting under the "scale," but riding upon it, as indicated. The tool will be dulled rapidly by the abrasive action of the scale, and the results will be very unsatisfactory.

In designing a boring tool for a hole of this kind, the cutting point of the tool should be shaped as shown at *E*. When made in this way there is no tendency for the tool to ride on the scale; and it will therefore keep the position indicated, will not dull up rapidly nor deflect, and consequently will produce a much better hole. When piloted bars are used, it is not necessary to take as much care to avoid a condition of this kind, because the bar is supported and cannot deflect. The point of the boring tool should be as blunt as possible, and still retain a sufficient cutting edge. The metal should be allowed to remain behind the cutting point and should not be ground away any more than is necessary for clearance. Generous sizes of tools with plenty of metal at the cutting point carry away heat more rapidly and stand up better for production work.

A point of importance is the position of the tool with respect to the center of the work. If placed directly on center, as shown at *F*, any slight deflection of the tool causes it to dig into the work. If placed a trifle below center, as shown at *G*, this action is still more apparent. If placed slightly above center as shown at *H*, any deflection caused by the pressure of the cut does not tend to throw the tool into the work. Hence, there is no chance for chatter from this cause. Boring tools are usually placed directly on center; but it is better to position them a very small amount above it, say, from $\frac{1}{32}$ to $\frac{1}{16}$ in., depending somewhat on the diameter of the work being bored. This practice is not universally followed, but it will be found an advantage.

Another point of importance is the position of the tool in a horizontal or vertical plane. The turret does not always index exactly the same, and any variation in the index position is multiplied at the end of a long bar. If the tool is placed in a horizontal plane, as shown at *K*, the diameter of the hole *L* will theoretically be produced to a size corresponding with the amount of fluctuation in the position of the bar. Errors in indexing when the tool is placed in this position will frequently cause a variation in the work of from 0.005 to 0.010 in. This point is clearly brought out by the diagram at *M*.

The end view at *N* indicates the variations in diameter which would be caused if the tool were set in a horizontal plane and if the turret did not index correctly. The dotted lines show the size of hole which would be produced under these conditions. It is much better to place the tools in a vertical position as shown at *O*.

When they are so placed the cutter variation caused by errors in the indexing may be considerable, and yet the diameter will be changed only a small amount, as indicated by the dotted lines.

It is often desirable to use an adjustable holder for a boring tool which is required on small work. The principal use of holders of

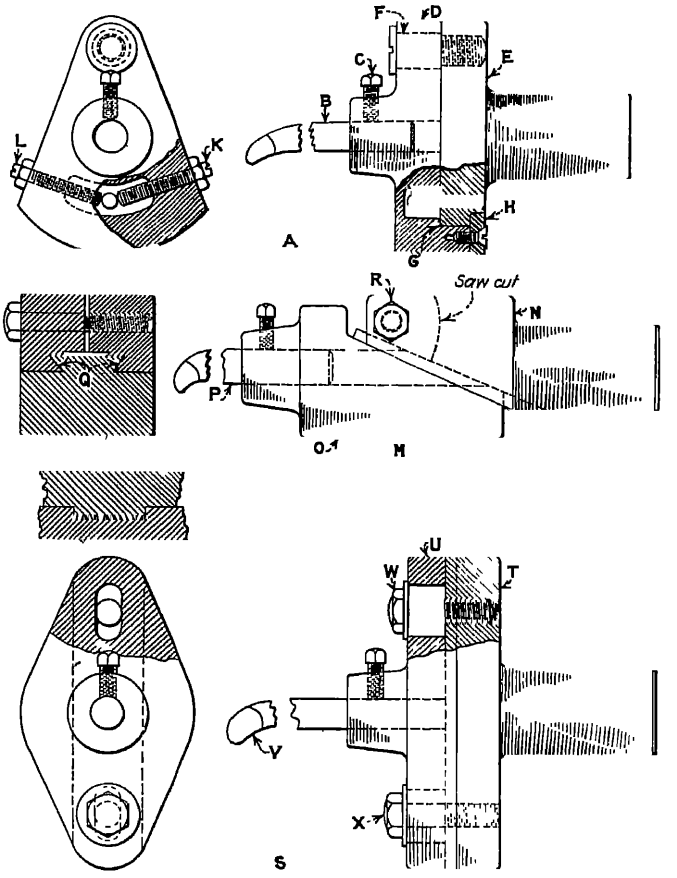


FIG 93.—Adjustable boring toolholders

this kind is for automatic screw machine work, or for any other kind of work in which a forged boring tool not adjustable in itself is used. Several examples of holders for this purpose are shown in Fig. 93. The example at *A* shows a forged tool *B* held by means of a setscrew *C* in a movable member *D*. This member is fastened to a holder *E* which fits the turret of the machine. The

member D is pivoted on a shouldered screw F, so that it can be adjusted to either side of the center line of the turret. It is fitted at G and gibbed at H, so that there is no lost motion.

In adjusting the tool B, the setscrews at K and L are operated to throw the tool to one side or the other of the center, as may be required. The tool itself may be held in a vertical or horizontal position, and it is easily possible to adjust it for varying diameters within its capacity. This design is manufactured in more or less modified form by several machine tool builders specializing in turret lathe work. It would be easily possible to use this holder on the cross-slide of an engine lathe or even in the tailstock by providing a suitable bracket or a taper shank.

Another type of adjustable holder is shown at M. It is somewhat out of the ordinary in general design. The shank N is designed to fit the turret of the machine and is dovetailed, as shown in the sectional view. The holder O contains the tool P, which is held by the setscrew as indicated. The dovetailed portion Q fits the dovetail in the holder, and adjustments are made by sliding it backward or forward along the taper. When the desired position has been reached the screw R is tightened, thus holding the tool firmly. The end of the shank is slotted as indicated, in order to provide for the binding action.

Another type of adjustable boring toolholder is shown at S. This device consists of a holder T on which is mounted a member U, fitted to slide vertically on the holder. The tool V is held in the usual manner by a setscrew, and adjustments are made by sliding the movable member up and down, and then tightening the screws at W and X when the desired position has been reached. In general it is not necessary to provide holders of this sort with very much adjustment when they are to be used for screw machine work. From $\frac{1}{16}$ to $\frac{1}{8}$ in. is usually sufficient, although more can be provided to suit special cases.

Fastening Tools in Holders.—Tools for boring bars may be either round or square. If made from round stock they ordinarily fit the hole easily; while if square, bright, drawn stock is used, they do not generally fit closely, but are more or less loose. For a factory using a comparatively small number of boring bars in its production work, the round shape is to be preferred, because it is easier to make a round hole in a bar than it is to make one which is rectangular or square. Square tools have some advantages over those of a round section, but if they are to be adopted as a

standard a set of broaches of various sizes must be made up, so that the holes can be put in the bars cleanly and without trouble.

Tools are held in boring bars in various ways, depending upon the type of cutter, its size and general shape. The essential points in holding are rigidity and convenience of adjustment. The thrust of the cut is to be taken against the solid portion of the bar; but in actual practice convenience often requires the set-

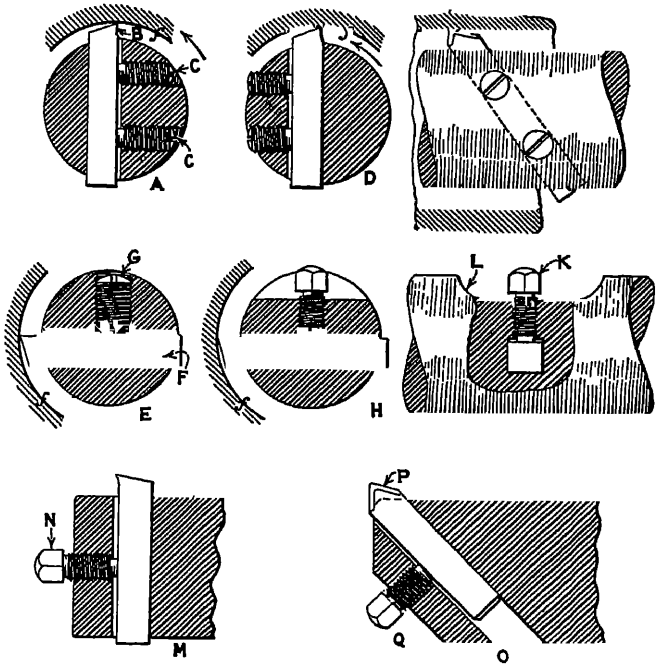


FIG. 94.—Holding round or square boring tools.

screws be placed in such a way that the thrust comes against the screws themselves.

In Fig. 94 is shown a sectional view of a boring bar at *A*. The tool *B* is so placed in the bar that the cutting edge is in line with the center of the bar. The tool is held in place by two setscrews, shown at *C*. The thrust of the cut is in the direction indicated by the arrows, but if this bar were to be used on turret lathe work, the screws placed as shown would be at the rear of the machine, and the operator would not find it convenient to adjust them without going around behind the machine. In the example *D*

the setscrews take the thrust of the cut, but if they are substantially made there will be no difficulty in this respect and the operator will find it much more convenient to make adjustments.

Incidentally, it may be stated that small setscrews with slotted heads should not be used for holding the cutter, because it is difficult to set them up tight enough to hold it, and also because the slots are apt to be broken or mutilated by long use. A hollow-head setscrew will be found an advantage in holding

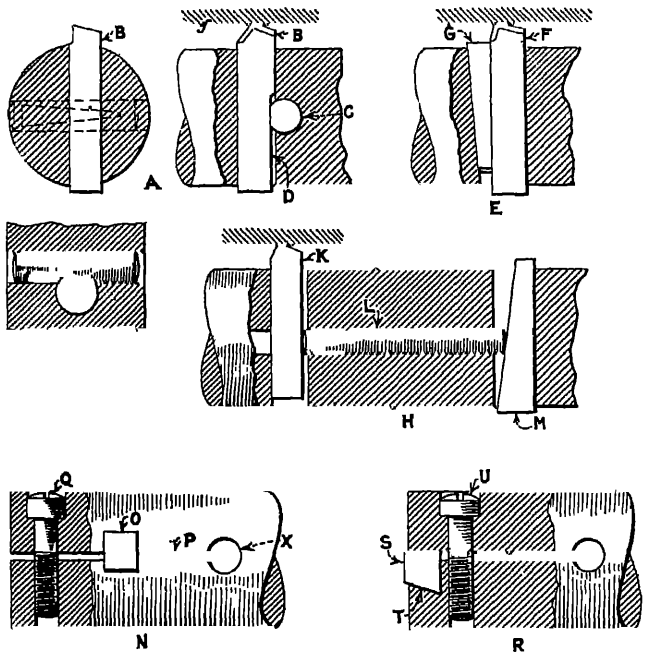


FIG. 95.—Other methods of holding tools.

cutters and boring bars. If there is plenty of room, it is not objectionable to use a square-head setscrew. In the example shown at *E*, the tool *F* is held by a single screw *G*, but this method should be avoided and two screws used whenever possible. In the example *H* a square-head setscrew *K* is used. The bar is cut away at *L*, so that the setscrew will not project beyond the outside diameter of the bar.

A cutter which is placed close to the end of a boring bar may often be held as shown at *M*, when the bar is not piloted. The setscrew *N* is placed in the end of the bar as indicated. If the

size will permit, it is better to use two screws. Many cases are found when the cutter must project beyond the end of the bar itself. An example of this kind is shown at *O*, in which the tool *P* projects slightly. The method of holding in this case is by means of a setscrew *Q*, although here also two screws would undoubtedly be an advantage.

In holding tools in small bars or when space is limited, other means must be provided. Several examples of this kind are shown in Fig. 95. One of the best known of these methods is shown at *A*, in which the tool *B* is held in place by a straight pin *C*, one side of which has been milled to a taper. The tool is flatted at *D*, and the pin driven firmly into place against this flat. This method is used to a great extent in holding many kinds of cutters. The principal objection to its use is the difficulty of adjustment.

The method shown at *E* is very objectionable. Here the tool *F* is held in place by means of a wedge *G*. It is practically impossible to set a tool of this kind to a given diameter and hold it firmly, because the wedge *G* when set up always carries the cutter with it slightly, thus changing the setting. Another method employing the wedge principle is shown at *H*. In this case the tool *K* is clamped by means of the steel rod *L*, which is acted upon by the wedge *M*. There are certain cases where some arrangement of this sort may be found necessary.

Another method of holding a rectangular tool is shown at *N*. The tool *O* is close to the end of the bar and is of rectangular shape, as shown. The bar is slotted at *P*, and the screw *Q* is used as a pinch binder to draw the sides of the bar together, thus holding the tool securely. This arrangement may also be found very convenient at times. It is advisable to make the hole *X* of fairly large size in order to help the spring action.

In the example *R* the tool *S* is held so that it projects a trifle beyond the end of the bar. The tool is shaped so that it has a slight angle at *T* which fits a corresponding slot across the bar. As in the preceding case, the bar is slotted to allow for a pinch-binder screw at *U*. The advantage of this type is that the tool can be securely held either straight or at an angle, and also so that the cutting edge is at the end of the bar.

The matter of provision for the adjustment of cutters in boring bars is an important one, yet it is not generally given the consideration to which it is entitled. The method provided should

be such that it will be convenient, easy of access and accurate. There is some difference of opinion as to whether adjustments can be made more conveniently by means of a wrench on a square-head screw, or by the use of a screwdriver in the slotted end of a screw. The writers favor the latter method, as the position of

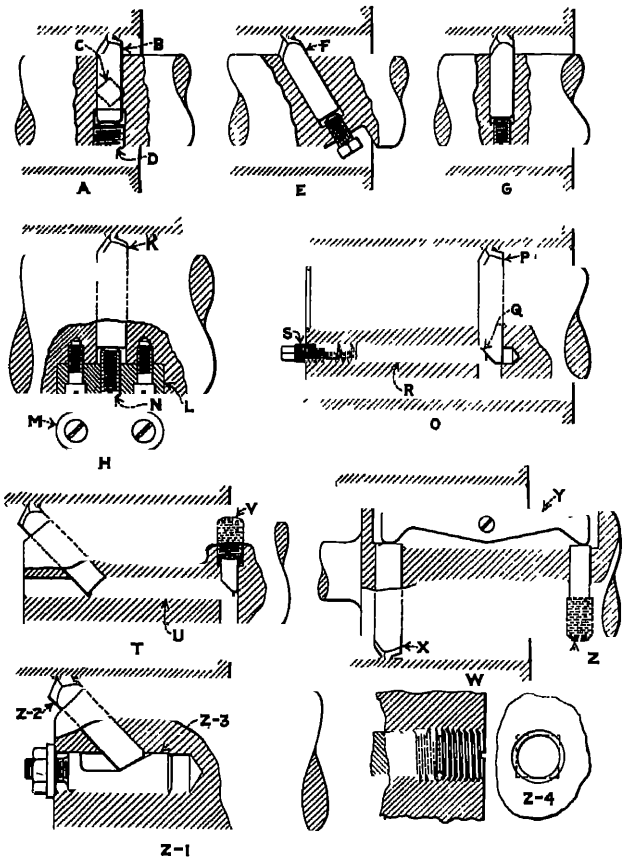


FIG 96.—Methods of adjusting boring tools

the tool can be more easily controlled by means of a screwdriver than by a wrench. Existing conditions in the construction of the bar and the location of the cutter make it necessary to use different methods, but the matter of convenience and ease of setting should always be considered.

In Fig. 96 are shown a number of examples to illustrate the different methods which can be used for the purpose mentioned.

In the case *A* the tool *B* is set straight across the bar and held by a setscrew at *C*. The adjustment provided for this tool is made by means of a headless slotted screw *D* of slightly larger diameter than the tool itself. The hole is, therefore, tapped nearly half way through the bar in order to permit of considerable adjustment. This tapping of the hole takes away a part of the bearing for the tool, and it is therefore objectionable. A better arrangement is shown at *E*, in which the tool *F* is backed up by a screw smaller than its own diameter. This screw can be used with a filler block to follow up the tool until the latter becomes so short that the limit of its life has been reached. A similar arrangement using a headless screw is shown at *G*.

In the example *H* the tool *K* is of rectangular shape and the hole is broached entirely through the bar. To provide for adjustment, a recess is milled at *L* and into this the block *M* is fitted. A headless setscrew, shown at *N*, is used to make the adjustment. It may be well to state here that adjusting screws are preferably made of fine pitch, usually between 24 and 30 threads per inch.

Another method of adjustment sometimes found convenient for confined situations is shown at *O*. The tool *P* is ground to an angle of 45 deg. at *Q*; and against this surface the shoe *R* bears, so that when it is acted upon by the screw *S*, it will force the cutter outward. This construction can be varied somewhat by using a cone point screw instead of the shoe.

A method that can be used to operate and adjust a cutter which is inconveniently situated is shown at *T*. This design also employs an angular principle by using the rod *U*, which is beveled at each end and acted upon by the screw at *V*. A method like this can hardly be recommended, except in extreme cases where difficulty is found in placing a screw so that it will act directly against the end of the cutter. In the example *W*, the tool *X* is adjusted by means of a lever *Y* which lies in a slot on one side of the bar. It is acted upon by a screw *Z*, which causes the tool to move outward when pressure is applied.

In the example *Z-1* the tool *Z-2* is adjusted by means of a plug *Z-3*, which is tapered as indicated and drawn up by means of the nut at the end of the bar. This method provides exceptional stability under the tool and the adjustment can be readily made.

When rectangular tools are used, two methods are employed; one of these is to tap the rectangular hole so that a screw of suit-

able diameter can be used and the other is to drill a hole of slightly larger diameter than the rectangular one and fit it with a screw, using if necessary a small shoe between the end of the screw and the tool. This method is illustrated at *Z-4*.

Flat cutters are frequently used in boring bars instead of the round or square variety which have been described. There is considerable difference in the cutting action, as the flat-blade

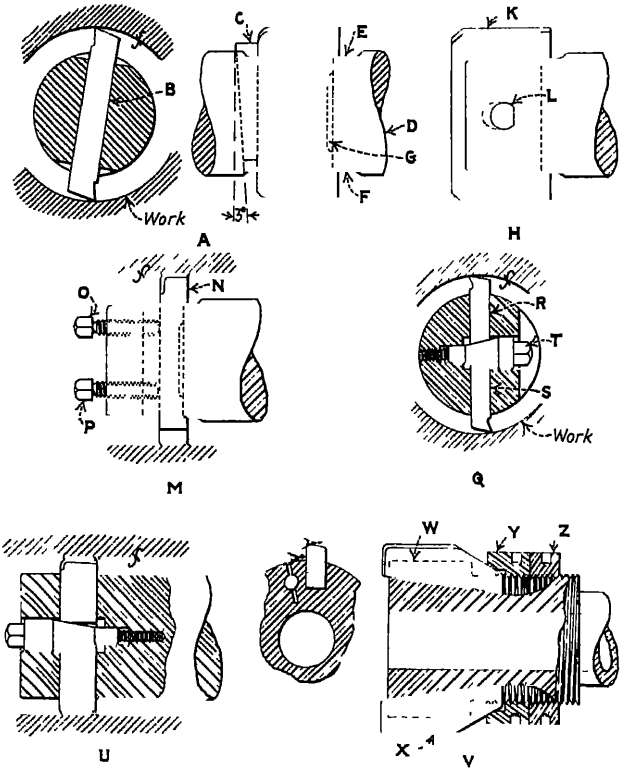


FIG 97.—Flat cutters for boring bars

type is usually double ended so that each end cuts. Strictly speaking, boring bars with flat cutters do not generate the hole; but they are nevertheless very useful, as they are capable of removing considerable stock. There is, however, no adjustment for diameter other than the grinding of the cutter to the specified size. This construction avoids the possibility of errors caused by an inaccurate setting of the cutter, and the tool can be used with considerable success by inexperienced workmen. It is

subject to several objections, however, the first being the fact that the hole is not generated. The second is that there is no up-keep to the cutter, so that after it becomes worn it must be reground and used for some diameter smaller that that for which it was originally intended. For certain classes of work and under some conditions, excellent results can be obtained by the use of flat-blade cutters of various kinds.

In Fig. 97 is shown at *A* a portion of a boring bar furnished with a flat-blade cutter *B*. The method of fastening this cutter in place in by means of a wedge *C*. The bar *D* is milled away on two sides at *E* and *F* equidistant from the center. The cutter is carefully fitted with shoulders which exactly fit the bar at these points, thus giving it the correct location. Relief is provided at *G*, so that the action of the wedge *C* causes the cutter to bear only at the outer portions of the bar. A wedge like that shown is rather objectionable for several reasons. One of these is the fact that there is a slight tendency to distort the bar, another is that it is inconvenient, and a third reason is that the projecting end of the wedge may interfere with chip clearance. It is often used, however, although there are other methods which are to be preferred.

The example *H* shows an end-cutting, flat-blade boring tool at *K*. This tool locates in the bar in the same manner as that previously described, but it is held in position by means of a round pin *L* flatted off on one side to a taper. When this pin is driven into the bar it enters a hole in the cutter and draws the latter back strongly against the shoulder. This method is much superior to the wedge shown at *C* and is used in many bars for holding both flat cutters and the round variety.

Another method which can be used for a cutter of this general type is shown at *M*. The cutter *N* is of rectangular shape and locates in the bar as in the previous example. It is held in place by means of two setscrews at *O* and *P*, instead of by a wedge. A point of importance in connection with the use of double-end cutters is the grinding of the tool at the point, so that the opposite faces are in line with each other and at the same time in line with the center of the bar. The sectional view at *A* brings this point out clearly.

Flat cutters are sometimes made so that they can be adjusted for diameter. Various methods are in use, several of these being shown here. In the example *Q* the tools *R* and *S* are separate,

and are expanded by means of the special tapered screw *T*, which bears equally on the inner end of each cutter. A suitable method of fastening the cutter after it has been adjusted must be provided. In the example *U* the principle used is much the same, but the adjusting screw enters the end of the bar instead of the side. Care must be taken in either of these two cases to make sure that the screw has a cylindrical bearing on both sides of the taper, in order to insure accuracy.

Another method of adjusting flat-blade cutters is shown at *V*. The cutters *W* and *X* are fitted to the taper slots shown, and adjustment is obtained by means of the lock nuts at *Y* and *Z*. The nut *Y* is beveled, so that it has a holding-down action on the cutters. The other end may be secured by means of a tapered pin in a slot, as indicated in the end view. There are other methods of adjusting and fastening cutters of this kind, but the principles illustrated here cover those which are best known and most used in tool designing.

Piloting Boring Bars.—The advantages of a piloted boring bar have been previously mentioned, but the method of piloting has not been taken up. Fig. 98 shows a number of examples which illustrate the use of the pilot in connection with bars for boring. In the example *A* the work *B* is held on a faceplate fixture in which a bushing *C* is fixed. The bar *D* has a pilot *E* which enters the bushing, and guides as well as supports the bar under the pressure of the cut. This is the simplest type of piloted boring bar. It is, perhaps, unnecessary to state that both bar and bushing should be hardened and ground.

Another example, shown at *F*, indicates a method which can be used for piloting a boring bar used in a blind hole in the work *G*. The fixture is so arranged that it carries a bushing *H* in a suitable position to act as a support for the bar *K*. The bushing is a sliding fit on the bar and remains on it at all times, as indicated by the dotted lines at *L*. When indexing the turret the bar is pulled out and carries the bushing with it. It depends somewhat on the size of the hole whether this arrangement is necessary, as in some cases it might be possible to make a bushing larger than the diameter of the hole which is to be bored and proportion the bar accordingly. When a blind hole is to be machined, a method like this can often be used to advantage.

Another method of piloting bar for a blind hole is shown at *M*. Here the bushing *N* is supported in a bracket *O* which is attached

to the ways of the machine. The bracket may be made in such fashion that it can be thrown back out of the way if a number of tools are being used in the turret in the same operation. The method of attaching to the ways of the machine is clearly shown.

When a large diameter is to be bored, like that shown at P, the work may be supported and located on a pilot Q, which is fastened

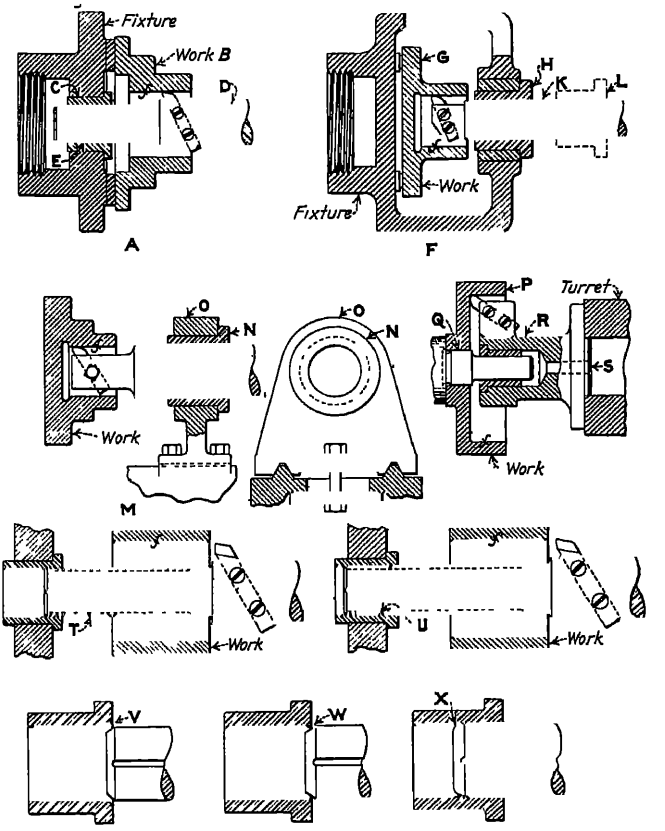


FIG 98 —Methods of piloting boring bars

into the face plate fixture. The toolholder R can be furnished with a bushing, as indicated, so that the pilot on the fixture will enter it and steady the tool against the pressure of the cut. This construction assists in producing accurate work. Care should be taken whenever a pilot is used to provide means for the releasing of any air compression which may be caused by the pilot entering

a blind hole. The hole *S* takes care of the matter in the example shown.

The bar *T* is not greatly different from that shown at *D*, except that it is provided with oil or chip grooves. Many manufacturers provide all boring bars with grooves of this sort, both for the purpose of lubrication and to prevent trouble which might be caused by chips being carried into the bushing and scoring both it and the bar. A point of importance in connection with the length of the pilot should be mentioned here. In the example *T* the pilot enters the bushing only a short distance before the cutting tool starts on the work. It is much better to proportion it so that it will have more support, as indicated at *U*. While the short distance that the bar *T* enters the bushing might be sufficient when both bar and bushing are new and are accurately ground to size, after a time both bushing and bar will become worn somewhat and the bushing may be "bell-mounted." As any freedom of motion here would produce chatter, it is better to allow for a greater length of pilot in the hole before the cutting tool starts.

In designing pilot bushings for boring bars it is common practice to make them with a round corner, as shown at *V*. This is not good practice, however, and should be avoided in all cases, as the round portion permits chips to gather on the bar and to be drawn into the bushing. If the bushing is made as shown at *W* with a sharp corner and if the bar is chamfered on the end as indicated, there will be no trouble caused by chips, even if the bar is not grooved. It is not advisable to round the end of the bar as shown at *X*, as this construction is likely to cause the same kind of trouble.

When several diameters are to be bored, it is customary to arrange the tools in one bar whenever possible. There are several points in connection with the arrangement of the tools which are important. They can best be illustrated by means of examples. Fig. 99 shows a piece of work *A*, which is bored to two different diameters by means of tools *B* and *C*. For work of this kind the tool *C* can be set either straight or at an angle, but it must be placed so that it will pass through the hole a short distance before the completion of the cut made by the tool *B*. If tools are arranged in this way, it is not necessary to be particularly careful as to the grinding of the faces of the tools. In the example *D* a similar condition is shown. Both tools *E* and *F* are placed at an

angle, but as the tool F passes through the work no great difficulty would be experienced in grinding the faces.

In the example G there are three tools, H, K and L. The tool H passes through the work, but tools K and L stop against the shoulder. The tool H can be set at an angle; but the tool K is also at an angle, and it must be carefully ground to preserve the distance from one shoulder to the next, and at the same time the diameter at the point must be taken into consideration. This means that a great deal of care would be necessary to preserve both shoulder distance and diameter when grinding the tool K. A better way to arrange the tools for a piece of work like this

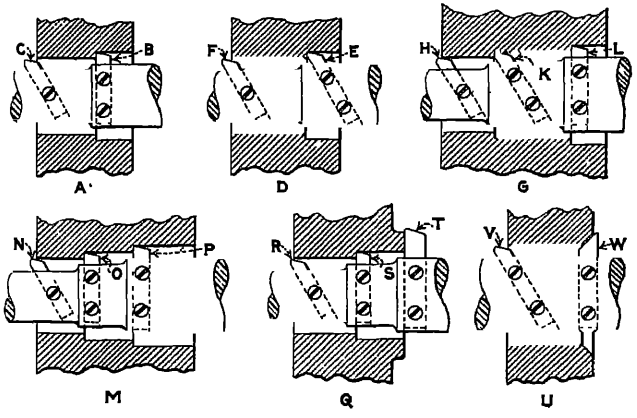


FIG 99 —Arrangement of tools in multiple boring bars

is shown at M. Here the tool N extends through the work and is set at an angle. Tools O and P are set straight and the distance between the shoulders is determined by grinding the faces of the tools. The setting is much simplified when tools are arranged in this way. Another example, at Q, shows boring tools at R and S and a facing tool at T. The tool R extends through the work and is set at an angle, but both of the tools S and T are set straight for the reasons previously mentioned.

In the example U, tool V extends through the work and tool W cuts a chamfer, as indicated. The tool V is set at an angle while that at W extends straight across the bar. The principles shown in these diagrams are valuable, yet they are frequently not considered by a tool designer. Multiple bars are often made with three or four angular tools which are intended to bore diameters

and preserve shoulder distances at the same time. When this is done it is often necessary to make up a special gage for grinding, and a great deal of trouble is usually experienced in setting the tools correctly.

It is not always profitable to bore large and small diameters at the same time on account of the difference in the speed at the various points. A great deal depends upon the work which is being done in combination with the boring tools. If an outside

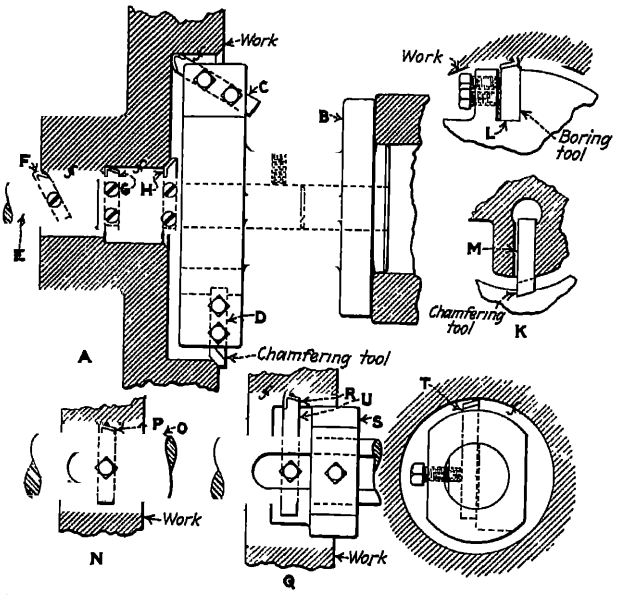


FIG. 100 —Multiple boring bars for large and small diameters

diameter is being turned while a small diameter is being bored, the speed of the work must be proportioned according to the speed of the largest diameter. In such cases, it is good practice to bore as many diameters at once as the tool set-up will permit.

In Fig. 100 is shown an example at *A* which requires a multiple set up of boring tools. A special holder *B* is fastened to the turret face and contains a boring tool *C* for boring the large diameter and a chamfering tool *D* for finishing the angular portion. The holder *B* is also provided with a multiple boring bar *E* in which are three tools, *F*, *G* and *H*, used for boring, cutting to shoulder and chamfering, respectively. In the matter of setting the tools for

work of this kind, the principles which have been previously described should be employed. The detail at *K* shows a method of fastening the tools in the holder. The casting is slotted out at *L* and *M* to receive the tools, and square-head setscrews are used to hold them rigidly. No provision for adjustment is made in either case, other than by hand. It would be easily possible to provide the tool *C* with a backing-up screw for convenient adjustment.

When bars of a standard type are being used, there is an occasional necessity for boring a hole considerably larger than that for which the bar is designed. In the example *N*, *O* is a standard bar provided with a square tool *P*. It is evident that for other considerably larger diameters the tool would overhang from the bar so much that it would be likely to chatter. Provision can be made for this condition, as shown at *Q*, in which the cutter *R* is much longer than that shown at *P*. A head *S* is fitted to the bar in such a way that the tool is well supported by it. This method is of considerable advantage when machines are equipped with standard bars which must be adapted to a considerable variation in the diameter of work. Care must be taken when using a supporting member of this kind to make sure that it fits the tool closely at the points *T* and *U*, so that it will resist the pressure of the cut in both directions without permitting vibration.

CHAPTER VIII

FACING TOOLS

CUTTING ACTION OF FACING TOOLS—COUNTERBORES, SHOULDER TOOLS AND ADJUSTABLE CUTTER HEADS—ADAPTATION OF STANDARD TOOLS—ARRANGEMENT OF BLADES IN CUTTER HEADS—ROUGHING AND FINISHING HEADS—COMBINATION AND UNIVERSAL TOOLS

Cutter heads of various sorts are used for boring and facing, sometimes in combination with boring bars and at other times alone. Tools may be used for only one surface which is to be faced, or they may be utilized for turning, boring and facing a number of different diameters or shoulders. The shape of the work and the material to be cut influence the design to a great extent, particularly with respect to the form of the tools and their adjustments. If intended for boring only, the head may be single or multiple, according to the work which it has to do. A cutter head can often be used to advantage for rough boring large diameters when a great amount of stock is to be removed.

Cutting Action of Tools.—We have already considered the position and shape of tools used for turning and boring, but the operation of facing has not been taken up. In turret lathe work, facing operations are often attended with considerable "chatter," which may be due to a number of causes, such as back-lash in the spindle of the machine, loose gibbing, a worn feed screw, incorrect feeds used on the machine, improper methods of holding work, and position or shape of tool with respect to the work. The machine troubles can usually be easily remedied, but the position and shape of the tools used are both dependent on the design.

If a turret lathe spindle is slightly loose in its bearings, there will be chatter in the facing operation, no matter what kind of tools are used. End play in the spindle, also, is likely to produce more or less chatter, but this trouble can be easily remedied by proper adjustment. A loose-fitting bearing may require re-babbitting before satisfactory results can be obtained; or, if

taper bushings are used as spindle bearings, it may be necessary to take them up in order to remove all vibration. When the turret gibs are not set up snugly, chatter may develop due to a lift at these points, but the remedy for this condition is obvious. Oftentimes certain types of tools may appear to produce chatter and the tools will therefore be blamed, when in reality the cause lies in the various adjustments of the machine itself.

The matters of feeds and speeds also are important in their connection with the use of facing tools or cutter heads. The correct feeds and speeds can only be determined by experiment,

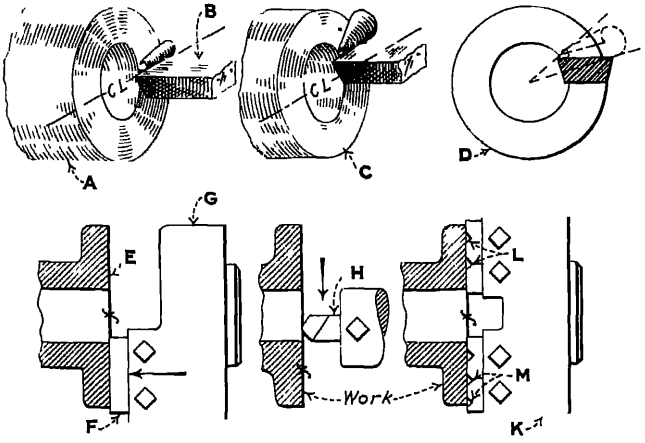


FIG. 101 —Cutting action of facing tools.

as the quality of the material, the depth of the chip and the amount of surface which is being faced all govern the feed to some extent. A great many facing operations do not use machine feeds at all, the required power being applied entirely by hand. When cutter heads are used in combination with facing tools, the feeds may be used part way on the work, but the final finishing is done by hand pressure.

The amount of surface to be faced affects the design of tools strongly. On certain kinds of facing operations, too many teeth or cutter blades acting on the same surface will cause the tool to function improperly on account of the pressure required to force the tools into the work. Illustrations of this condition will be given later.

In considering the cutting action of a facing tool used in the turret lathe, we must pay attention to the position of the tool

with respect to the center of the work. Fig. 101 shows several examples which illustrate these points. In the example *A* a facing tool *B* is shown on the center line of the work. A tool set in this way removes the metal without any shearing action, as the chip is removed on a line radial with the center of rotation of the work. In order to obtain a shearing action and make the cutting easier, the tool should be placed above center, as shown at *C*. The diagram at *D* illustrates the cutting action, and clearly shows the reason why it is so much easier when the tool is placed in this position. From these examples we determine a point of importance in connection with the design of facing tools; that is, that all tools of this nature should be placed ahead of center. If the tool is placed considerably below center a shearing action is also obtained, but the chip tends to crowd toward the center and would be likely to clog up tools after continued use.

In facing wide surfaces such as that shown in the example at *E* a flat tool *F* held in a holder *G* may be made to produce good results, providing it is set well above the center and held rigidly so that it will not chatter. It is much wiser to avoid broad cuts if possible, particularly when cutting steel; and if a crossfeeding movement is available, it is better to use it rather than to make a wide facing tool like the one illustrated. With a single-point tool like that shown at *H* the stock can be removed quite rapidly by feeding in the direction shown by the arrow. Much depends upon the number of tools which are used for other operations on the work, and it is not always possible to obtain a single-point effect in facing.

By using a cutter head like that shown at *K*, wide surfaces can be faced successfully. It is a good idea to notch the cutters, as shown at *L* and *M*, making the notches in such a way that they will overlap each other and not produce a grooved surface on the work. It is better to use two cutters as in the example *K*, rather than a single cutter as shown at *F*, although the single cutter can be made to produce results when used with care. The double cutter, however, gives a balanced effect and will be found better in ordinary practice.

Counterbores and Shoulder Tools.—Facing tools are often made in the form of a flat cutter like that shown at *A* in Fig. 102. They may be used in connection with a boring bar or separately, according to the requirements of the work. When a tool of this

sort is used, it should not be ground radially, but each side should cut ahead of center an amount equal to half the thickness of the cutter. When made in this way, the cutting action is easier and the upkeep of the tool simpler. Very good results can be obtained by this design when the surfaces to be faced are not broad, but are like that shown. An end mill of the shell type is often used for a facing operation, as in the example shown at *B*. It is often possible to use a standard mill for the purpose, inserting a pilot bar *C* of suitable size and driving the mill by means of a collar *D* with a suitable key at *E*. Face mills used in this way should have teeth cut ahead of center. Many times it will be found profitable to grind away some of the cutting teeth in order to make the

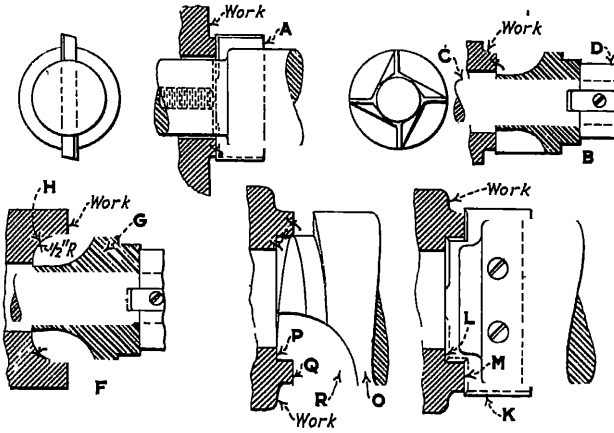


FIG 102.—Counterbores and shoulder tools.

cutting action easier, if standard tools are used. The fewer the number of teeth, the easier the tool will cut; and the pressure required is not so great. The number of teeth in contact is a very important point in connection with face mills.

A very good illustration is shown at *F*, in which a special face mill *G* is used to form a large radius *H* in the bottom of a cast-iron bushing. In this particular example, the diameter of the cutter is 3.185 in. and the radius to be cut is ½ in. The writers designed this tool with eight teeth, but found on trial that it was almost impossible to force it into the work with sufficient pressure to make it cut. The tool was removed from the bar, and every alternate tooth was ground away so that it did not cut, after this another trial was made and the cutter was found to work

satisfactorily. In analyzing this condition, it will be seen that the total surface covered by the eight teeth amounted to over 5½ in. A man would scarcely attempt to face a piece of work with a cutter 5½ in. wide, even if it were to be notched in eight places. Why then should it be considered practical to do the same thing with a face mill having an equal amount of contact?

These points are not usually considered by a tool designer, yet they are of great importance. The same mistake is frequently found in tools bought on the open market, as many of these have too many teeth, so that they do not cut freely. In automobile accessory stores it is possible to purchase valve-seating tools for facing off the angular cast-iron surfaces on the cylinder blocks. The writers have never seen one of these tools properly made, as they usually have from twelve to sixteen teeth, and it is very nearly impossible to use pressure enough to make them cut on the valve seat.

In making up tools for facing two shoulders in a certain relation to each other when the two dimensions are important, the designer is confronted with the problem of preserving the two shoulder distances after the tool has been reground several times. A very common way of making a shoulder facing tool is shown at *K*, which is a flat-blade cutter for facing the shoulders *L* and *M*. The accuracy between these two shoulders must be preserved, which means that each time the cutter is reground the dimensions of these two points must be very carefully held to size. This makes an expensive grinding operation which can be avoided by using a different type of tool.

In the example *O*, the tool is circular in form and the shoulders *P* and *Q* are turned on the plug. Both of these shoulders are then faced off on a left-hand helix of the same lead for both shoulders. The tool is ground radially on the surface *R*, and as the shoulders *P* and *Q* are on parallel surfaces, the center distance is always preserved when grinding, without any difficulty. Tools of this nature will be found excellent when work of this kind is to be done.

Small Cutter Heads.—When facing small diameters a cutter head is often made up with a bar, either piloted or otherwise, as a single unit. Occasionally the facing tools are inserted in a separate collar, which is pinned to the bar or driven by means of a key. Designs like those shown in Fig. 103 are often made with four flat-blade cutters having their cutting edges on center

The blades are held in slots and fastened by some convenient method. This variety of facing head is really nothing more than a face mill with inserted blades. It will do good work, but has no particular advantages over the two- or three-blade variety. It takes considerably more pressure to cut, but this is not usually objectionable on small diameters, as the total amount of surface faced is not great.

In the example *A* the bar *B* is enlarged at *C* to give support to the four cutters *D*. The latter are of the flat-blade type set in

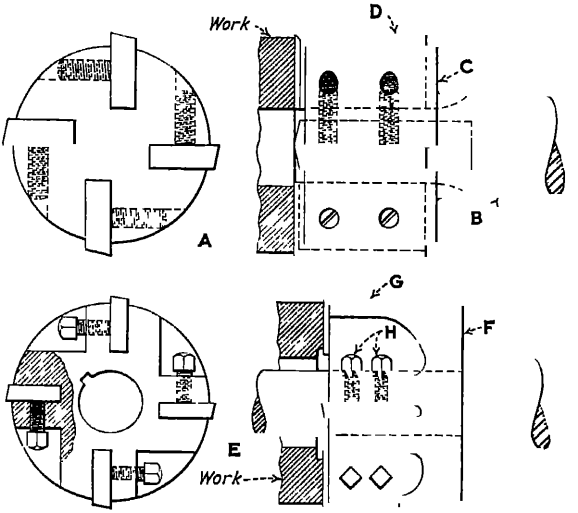


FIG. 103 —Small plain facing heads

slots in the bar, and the cutters are finished all over so that they fit the slots accurately. They are held in place by headless setscrews, as indicated. These setscrews may be of the hollow-head type or have slotted heads for use with a screwdriver. There is no fine adjustment to the cutters on this type of head, and the blades must be ground in position in order that they may all cut equally. If this is not done, considerably trouble may be experienced in setting them. The example shows the blades on center, but it is better if they are arranged slightly ahead of center, as previously mentioned.

Another example, shown at *E*, is a head of somewhat similar type except that the member *F* is separate from the bar and the cutters *G* are short. The blades are held in place by means of

two square-head setscrews *H*. The collar is milled away to allow ready access to the setscrews. This gives a very neat construction, and one which is inexpensive to manufacture. The blades in this example can be ground in the collar separate from the bar, if desired, but there is no fine adjustment for the blades. Both of these forms are in common use for facing work of small diameters.

There are various methods which can be used for adjusting cutter blades in a facing head. It is always difficult, however, to adjust all four blades so that they cut equally, although very good results can be obtained by making adjustments on the

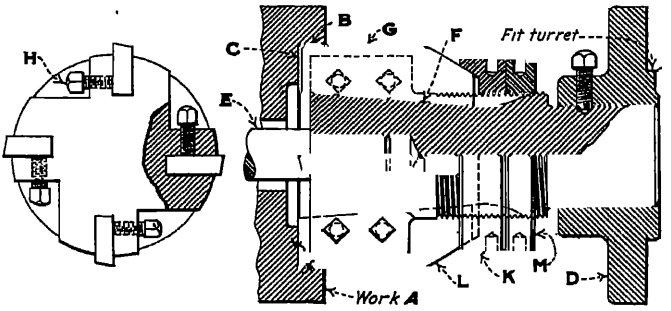


FIG. 104.

machine and setting each blade out so that it strikes the surface which is to be finished. When using this method, it is necessary to make sure that the faced surface is perfectly true, as otherwise the cutter setting would be incorrect.

In the example shown in Fig. 104 the work *A* is to be cut out at *B* and faced at *C*. The body of the tool *D* is fitted to the turret, and it has a pilot *E* at the forward end in order to guide and steady it during the cutting. The body of the tool is slotted in four places, as shown at *F*, these slots being cut on a back taper. The tools *G* are flat and are held in place by setscrews *H*. The blades are hardened and ground all over, and are fitted accurately to the slots, so that they have a bearing on the tapered portion. The collar *K* is countersunk at an angle, so that it fits the bevel *L* on the ends of the cutters. This collar can be adjusted until it is in contact with all the blades, thus tending to hold them down and giving opportunity for end adjustment. A suitable locknut is provided at *M*. This type of tool is not in

common use, yet there are certain cases where a design of this sort may be found convenient.

Care must be taken on any kind of a facing head that the overhang from the turret is not too great, unless proper support can be obtained by the use of a pilot. Not only must the body of the tool be well supported, but the cutter blades themselves must be held rigidly, and they should not project a great distance in front of the tool body. Various methods of adjustment will suggest themselves to the designer, and the examples given here represent some which have been used with success.

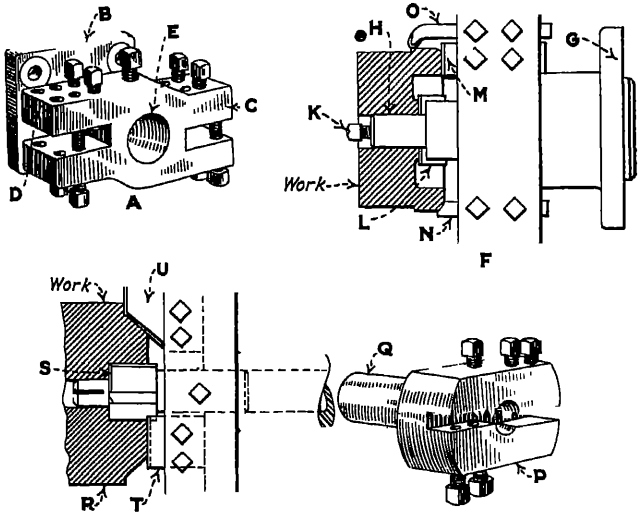


FIG. 105 —Standard forms of facing tools

We wish to point out again the importance of placing tools for facing ahead of center, although several of the examples given here show them directly on center. It frequently happens that tool designers do not appreciate the value of the shearing cut, and they place the cutters on center when they could just as well be placed ahead of center and thus obtain a better cutting action. We emphasize this point because it is not always done, and the writers consider it of sufficient importance to mention it several times.

There are a number of standard forms of holders in which cutters can be placed for various kinds of facing and turning operations. Several of these standard tools are shown in Fig.

105. In the example *A*, the body of the tool *B* is so arranged that it can be attached to the face of the turret. The extensions *C* and *D* are slotted and provided with a number of setscrew holes, as shown, so that one or more cutters can be placed in each side, according to the requirements of the work. A center hole is also provided at *E*, so that a pilot or a boring bar can be used in connection with the facing tools. Opportunities frequently occur in turret lathe work when a tool of this sort will be found useful; and, as the device is substantially made, it will withstand the strains imposed upon it. It is particularly desirable to use a tool of this sort with a pilot or a piloted boring bar, except in cases when very light cuts are being made and it may be found unnecessary.

An example showing the application of the same tool is given at *F*. The tool body *G* is fitted to the turret, and a pilot *H* is provided. In the end of the pilot a setscrew *K* holds the flat-blade cutter *L*, which is here used for facing a boss. The cutter blade *M* faces the flange, and a chamfering tool *N* breaks the corner. In addition, *O* is used for turning the outside diameter, and as all of the tools are used at the same time, the production obtained is exceptionally good.

Another type of tool which can be used for similar work is shown at *P*. It is provided with a shank *Q* which fits the turret of the machine. An application of this tool to a piece of work is shown at *R*. A piloted counterbore *S* is used to finish the pocket. A flat-blade cutter *T* faces the end of the hub, and a chamfering tool *U* cuts out the form and angle as indicated. The advantage of tools of this sort is that they are ready when wanted, and they can be quickly adapted to suit a given condition by the use of flat-blade cutters, boring tools, counterbores and the like. It is often possible to use holders of this kind for work which is to be made up rapidly, leaving very little time to design and build tools of a special nature that might otherwise be required.

Various methods of holding cutter blades in position can be used in facing heads, some of these methods being similar to those which have been described in connection with boring bars. The manner in which the blades are arranged in the cutter head naturally determines to some extent the method of fastening to be used, but there are several points of importance which should be carefully thought of when determining on the method of fastening.

(1) The thrust of the cut should come against the solid portion of the cutter head in the majority of cases. It is advisable, however, to consider the operator and his convenience when determining the position of the various screws, pins or other means of holding. This point is not of so great importance in a cutter head which is simply used for facing one surface; but when adjustments must be made for several diameters and a number of depths, it may cause a great deal of trouble.

(2) Cutter blades which are used for facing, as well as those employed for turning and boring, should be well supported as near to the cutting point as possible, in order that there will be no vibration during the cutting action. In other words, blades should not overhang on the cutter head any further than is absolutely necessary. It is often possible to carry out a portion of the head to form a support directly under the cutting point.

(3) The overhang from the turret is important, particularly when the tool cannot be piloted. If a pilot can be used in a bushing fitted in either the chuck or the face plate, a considerable overhang from the turret can be permitted; otherwise a great deal of trouble may be caused by chatter in the unsupported tool body. There are cases when a wide facing cut must be taken, and yet there is no opportunity for support by the use of a pilot. A bracket can be provided on the cross slide or on the ways of the machine to give support when a case like this is found. An arrangement of this kind was illustrated in connection with the design of turning tools for bar work. If it is not possible to support the tool by either of the two methods mentioned, the tool body can be designed so that it will have a certain amount of spring to it, excessive vibration being absorbed by this spring. The tool can be shaped as a "goose-neck" with the hinge point above the center of the work. It will then spring away and not dig into the work.

The points mentioned here should be considered by the designer when laying out cutter heads, and provision should be made to counteract any of the tendencies mentioned. It is not possible to give fixed rules for the design of tools like these, yet the designer should always keep in mind the results produced by the cutting action of the tool. The pressure applied must be counteracted or equalized in some way or other.

In Fig. 106 is shown a cutter blade *A* used in a head *B* and fastened in place by means of a taper pin *C*. The body of the

tool is slotted at *D* in such a way that the taper pin expands the slot slightly and contracts the portion surrounding the cutter, so that it holds the latter securely. Another method of holding cutter blades is shown at *E*. Here the blade is held in place against the body of the tool by a straight pin *F*, which is set into the end of the holder at a slight angle and tapered on one side, so that it acts as a wedge against the cutter.

In the example shown at *G* the body of the tool is slotted at *H* and is expanded by means of the tapered pin *K*. At *L* is shown another cutter blade which is held in place by a straight pin *M* set at a slight angle to the edge of the cutter and flatted

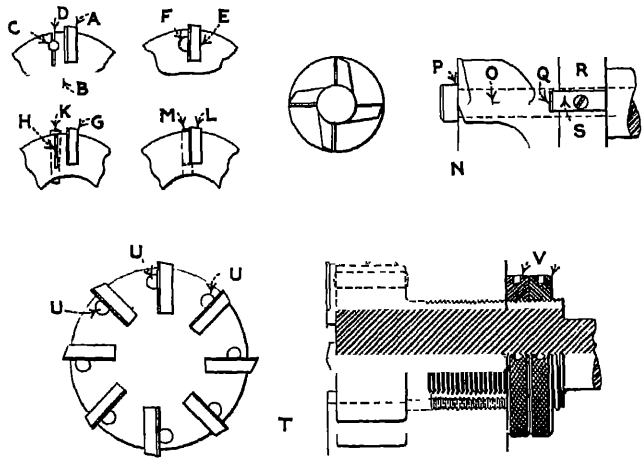


Fig 106 —Arrangements of cutters.

off on one side, so that it forms a wedge and holds the blade in place. All of these forms are used for holding cutter blades, and the method selected should be one which is most suitable for the work in hand. Care must be taken in using taper pins to provide a means of removing them when it is necessary to take the cutters out. This can be done by cutting a slot or drilling a hole in such a position that the pin is readily accessible.

The example at *N* shows a counterbore which is to some extent a facing tool, although it bores a hole and faces the bottom of it at the same time. In designing a counterbore, the material which is to be cut must be kept in mind, as it has an influence on the design. For cast-iron and brass work the flutes *O* are

often made straight, but for steel they are cut on a right-hand helix of about 15 deg. Counterbores for small diameters are often made with three flutes instead of four. When this design is followed, the size should be stamped on the body before fluting, as it is difficult to measure the diameter afterwards. Flutes should be cut deep enough, so that they come a trifle under the diameter of the pilot, in order to produce a clean hole. When the pilot is made as a part of the counterbore (which is not usually done), a groove is provided at *P* to give the necessary clearance for the cutting teeth.

The action of a counterbore is not conducive to first-class work, except for the facing of the bottom of the hole. The inside of the hole, when the work is of steel, is not usually very smooth; the cutting point is so sharp that, unless a very fine feed is used, the results obtained are not particularly good. However, as the hole produced by a counterbore is usually filled up by the body of a screw or a stud, its appearance is not of great importance. Different sizes of pilots may be used, and various methods of fastening the pilot in place. Revolving pilots are often employed in work where there is a possibility of marring a previously finished surface. In the shell type of counterbore shown, a slot is provided at *Q* for driving purposes. The collar *R* on the bar is fitted with two keys at *S*. Counterbores are often back tapered slightly for clearance.

An example of a multiple cutter head with adjustable flat blades is shown at *T*. The blades are held in place by means of straight pins with tapered sides as shown at *U*, and are adjusted in their slots by the two nuts at *V*, which are moved by means of a spanner wrench. These nuts are of assistance in setting the blades out to depth, and they also serve as a buttress for the rear ends of the blades, thus giving a substantial support. This type of facing head can be used as a counterbore for shallow holes, by setting the blades forward a sufficient amount. For deep holes it cannot be used on account of the trouble which would be caused by chips, as there are no flutes in the tool and no chance for the chips to work themselves out of the hole.

Mention has been made of facing heads which can be used for boring, turning, chamfering and facing. In high-production work tools of this kind are often used both for roughing and finishing operations. The type of head used depends to some extent upon whether the cut is for roughing or finishing. Fig.

107 shows a roughing head at *A*. The work to be done consists of boring the inside of the flange, turning the hub and facing the web. The two tools at *B* and *C* bore the inside of the flange and turn the hub, respectively. These tools are rectangular in shape and are set at a slight angle, in order to make diameter adjustments easily. The tools at *D* and *E* are used for facing the inside

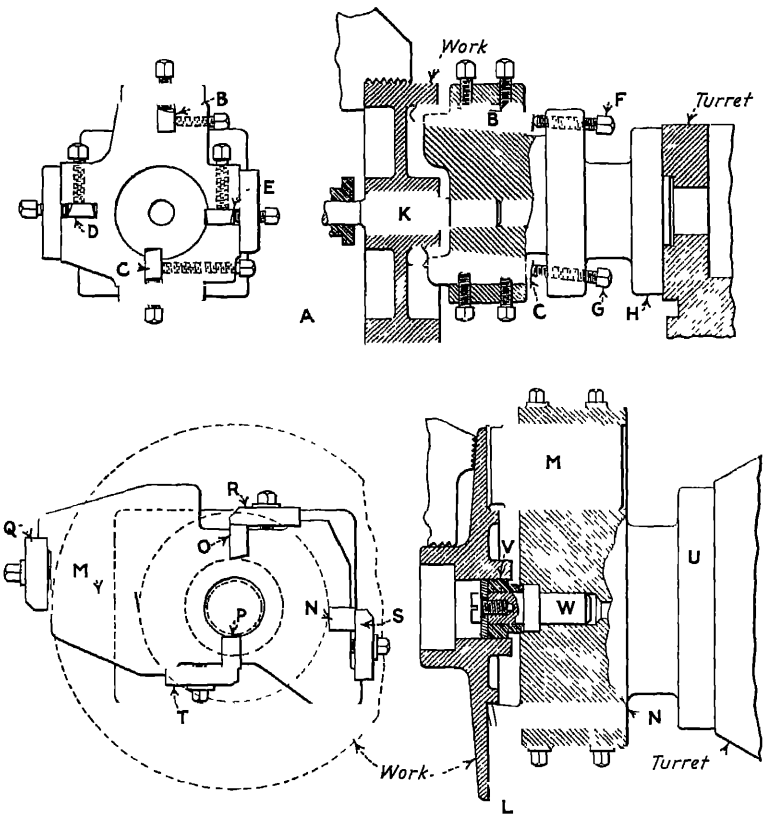


FIG. 107.—Facing heads for roughing and finishing operations.

of the web. These tools are wide enough so that one cut laps over the other slightly.

The various tools are held in place in slots in the body of the tool by means of square-head setscrews, as indicated. Adjustments are made by means of the screws at *F* and *G*. The body of the tool *H* is fastened to the turret of the machine, and the forward end is provided with a pilot *K* which enters a bushing

in the chuck, thus giving support to the entire tool. This pilot is important, as it steadies the cut and prevents trouble which might be caused by vibration due to a considerable overhang from the turret. The tools used in this cutter head are made of rectangular stock, squared up on two sides so that they fit the slots properly. It will be noticed that the thrust of the cut is taken by the body of the tool in some cases, while in others it comes against the setscrews. The reason for this arrangement is the convenience of the operator, the screws being placed so that they are easily accessible.

Another example of a cutter head is shown at *L*. This tool was designed as a finishing and sizing head. The cutter *M* finish faces the wide flange and the tool *N* sizes the shoulder at this point. The tool *O* cuts the recess, while *P* is used to face the end of the hub. All of these tools are made from hardened and ground stock of such size that they accurately fit the slots in the body of the holder. They are held in position by means of strap clamps, as shown at *Q*, *R*, *S* and *T*.

Adjustments are made by setting the tools up against a finished piece of correct size before setting up the clamps. The body of the tool *U* is of cast iron, and is bolted to the face of the turret. A revolving pilot is set in the end of the tool, as shown at *V*. The pilot is mounted on a stud *W* in such a way that it rotates freely when in the work, this being done in order to prevent marring or defacing the surface.

The two tools shown in this illustration are very good examples of the type of facing heads that the designer is frequently called upon to make. It is well to note that all facing tools are set well ahead of center, so as to produce a shearing cut, and attention is also called to the manner in which the facing tool *M* is used in connection with the sizing tool *N*. By using this method the size of the shoulder can be preserved accurately, even if the facing tool *M* becomes slightly worn. The method of applying tools of this sort to the turret is dependent entirely upon the shape of the latter, and this factor occasionally changes the design to some extent. A turret of the flat variety naturally requires a tool body of different shape than a hexagon type of turret. The matter of fastening the tool body to the turret is important; and in exceptional cases when very heavy cutter heads are used, it may be found necessary to drill and tap additional holes in the turret, in order to give sufficient stability to the tools.

Combination Heads.—For small work having several different shoulders and diameters which are to be machined in relation to a hole or a counterbored portion, cutter heads are frequently designed. A very good example of this type of cutter head is shown in Fig. 108, in which the work *A* is to be machined. The head *B* is of cast iron and is bolted to the turret. Through the center of the body a bar *C* extends, and at the front end of this bar a counterbore *D* is fixed, being driven by means of a key. A spotting drill passes through the center of the counterbore,

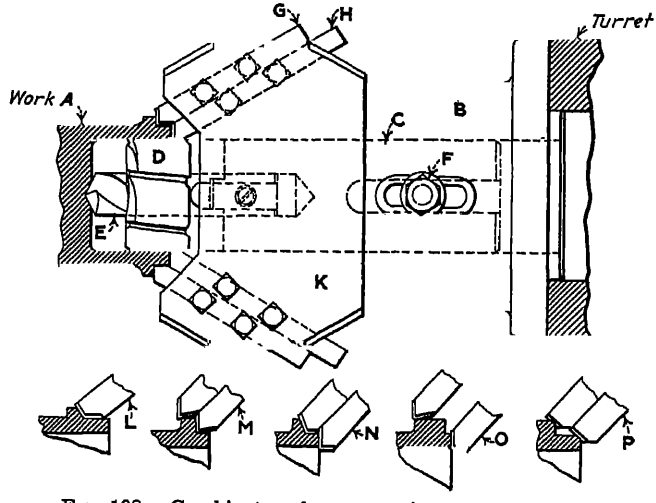


FIG. 108.—Combination facing, turning and boring head

as shown at *E*. Both the spotting drill and the counterbore can be adjusted independently, and in addition thereto, the bar *C* which holds them can be moved backward or forward and clamped by means of the nuts at *F*. The tools *G* and *H* are hardened and ground so that they fit the slot in the head *K*. They can be adjusted independently, yet they must be ground accurately in order to preserve the shoulder distances.

When a series of operations is to be performed on a piece of work like that shown, several cutter heads of this kind can be used with various arrangements of tools for the different operations, as shown at *L*, *M*, *N*, *O* and *P*. The same casting can be used in all these cases, and settings of the various tools can be accurately made by means of gages. For screw-machine work of moderate size, tools of this sort are very useful and extremely accurate

work is produced by them. The operations on the work can be arranged progressively, so that each tool does approximately the same amount of work. When used in connection with a counterbore and spotting drill like that shown, a part of the hole can be bored in one operation, another part in a second operation, and the final work in the last operation. The amount of time saved by this method is readily appreciated, especially when short diameters are to be turned and faced at the same time, as in the case illustrated.

It is possible to design a multiple facing head which can be used

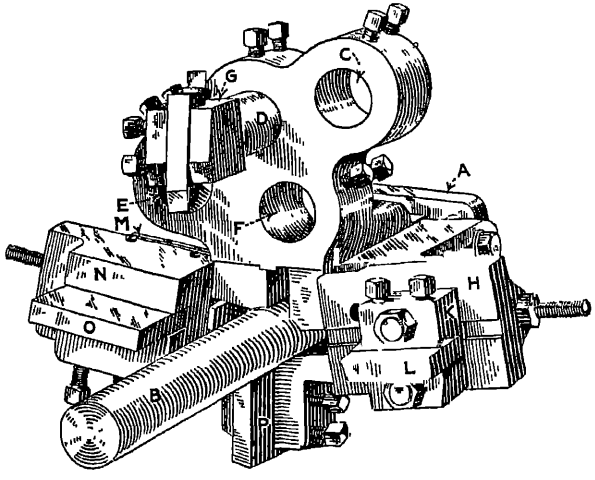


FIG. 109.—Universal facing and turning head.

for turning, facing and boring, and which will at the same time be so flexible in its design that it can be adapted to a number of different kinds of work within its capacity. An example of a tool designed for this purpose is shown in Fig. 109. The body of the tool *A* is of substantial section, and is arranged so that it can be fastened to the turret. This body extends outward and carries a bar *B* which acts as a pilot in a bushing, either in a faceplate or chuck. As it is easily removable, it can be replaced by a boring bar carrying several cutters, if desired. The upper part of the tool body has four holes *C*, *D*, *E* and *F* at different distances from the center of the holder. A toolholder like that shown at *G* can be furnished with a turning or boring tool for different diameters. In fact, several tools of this nature can be applied to the different

holes and suitable adjustments made to cover a considerable range of work.

An extension member or bracket at *H* is tongued to receive a block *K*, which can be adjusted and furnished with a cutter, as shown at *L*. On the opposite side of the holder another bracket *M* is shown. It also has a holder *N* in which a facing tool *O* can be placed. The body of the holder is slotted to admit a flat-blade cutter at *P*, and suitable setscrews are provided for holding it. The adaptability of a cutter head of this sort can be readily seen, as it can be made to handle a great variety of work by suitable changes in the tool blocks, turning tools and facing tools. Opportunities are frequent in general manufacturing for the use of tools of this sort, and the designer should consider making provisions for adjustment, so that the expense of a cutter head will not necessarily be borne by the particular job for which it is intended. If it is flexible enough, the head can be used for a number of different cases.

CHAPTER IX

RECESSING TOOLS

POINTS OF IMPORTANCE IN DESIGN—RECESSING TOOLS OPERATED BY CAMS, GEARS AND CROSS-SLIDE-SLIDE TOOLS—AUTOMATIC AND DOUBLE ACTING TOOLS—ARRANGEMENTS FOR RECESSING, BACK-FACING AND CHAMFERING

The cutting of a recess in a hole is one of the most difficult operations for which a tool designer is required to design tools. It makes a great difference what kind of a recess is to be cut; the general shape of it, the width and the depth all have an effect on the design of tools for the work. The size of the hole in which the recess is cut also has a pronounced effect upon the method used, as it is obvious that a recessing tool for a small hole is so restricted in size that it necessarily must be small and delicate.

A recess may be required narrow and deep, or it may be wide and shallow; it may be cut in a piece of work of small size, or of large diameter; it may be close to the front end of the work, or it may be quite a distance inside the hole. All of these conditions influence the design, and may perhaps require entirely different methods of handling, due to the difference in sizes or shapes.

Important Points in Design.—The following points are of importance in designing recessing tools:

(1) The material which is to be cut may be hard or soft, and may be a casting, forging or bar stock. Tools used on cast iron are made differently from those used on steel, and the cutting action is also markedly different. If the work consists of a casting in which a cored recess has been made, and this recess is to be finished by a recessing tool, two cuts will usually be necessary on account of the scale in the casting. If a single tool is used, it will dull quickly and lose its shape very rapidly, so that it cannot be depended upon to produce accurate work. Fortunately, however, the majority of recess cuts are not held to a very close degree of accuracy. If the material is of steel or any other metal which requires a lubricant, it may be necessary

to provide a means of supplying this lubricant to the cutting point.

(2) The width and depth of the cut are important because of the rigidity required for a tool on this kind of work. A deep recess which is at the same time narrow apparently would not require the tool to be supported as rigidly as if the cut were wide; yet a tool for a recess of this kind cannot deflect much without breaking, so that it is essential to make the construction as rigid as possible.

(3) The diameter of the hole determines the size of the bar which can be put into it, and therefore it is often difficult to machine a deep recess in a small hole. It is evident that the size of the cutting tools and other details of construction are limited by the diameter of the bar. When extraordinarily deep recesses are specified on a blueprint, it is advisable to discuss the situation with the engineer who is responsible for the design, and see if it is not possible to revise the drawing in such a way as to make the operation easier. This can often be done, providing the difficulty is found in the early stages of the work and before production is started. The shape of the recess and the permissible tolerances can also be modified to some extent, as a general thing. The greatest care is necessary in the design of recessing tools to make sure that the tool has sufficient clearance, so it will enter the hole without interference of any kind.

(4) The position of the recess with respect to the face of the work makes a considerable difference in the design of the tooling. It is often difficult to machine a recess which is located some distance from the face of the work. When the diameter is small a condition of this sort becomes serious, and it may be necessary to revise the method used entirely, and even in some cases to cut the recess in a separate operation, or otherwise change the method of handling so as to do the work from the other end. Under certain conditions a piloted tool may be used, thus giving support where needed, but this is not always possible.

(5) The rigidity of a recessing tool is very important, as any "chatter" is fatal to good results. If a long bar is used, it should be supported either by a pilot in a bushing, or by means of a special support on the cross-slide or the ways of the machine.

(6) Adjustment of the tool should be provided for, not only in relation to the depth of the cut, but also for longitudinal position.

There are occasional cases when the size of the hole is so small that there is very little opportunity to provide adjustment; but the matter should always be carefully thought of and everything possible done to take care of wear in the tool or changes in the longitudinal position caused by slight errors in grinding. The longitudinal depth may be determined either by an adjustment of the turret stops, or by collars which strike the face of the work or some portion of the fixture or pilot bushing. Ordinarily, a recessing tool is not required to work on the scale of the casting, although in some cases it is necessary. In such an event, both roughing and finishing tools will be required if accurate work is to be obtained.

(7) Recessing tools which are operated and controlled mechanically so as to have a positive action are to be preferred to those operated by springs. It is not always possible to control the tools in both directions by a positive movement, so that springs are often used. The designer should bear in mind that springs are not infallible, and endeavor to make use of mechanically operated parts as far as possible.

Kinds of Recesses.—A number of examples of work requiring recessing operations are shown in Fig. 110. There are doubtless many other forms which could be illustrated, but those shown cover the general requirements for this class of work. In the example *A* the work has a recess or pocket at *B*; and a piece of this kind is usually machined by a single-point tool either in a boring bar or in the cross-slide of the machine. It is possible to do the work with a sliding tool on the turret, using either hand or power feed, depending considerably upon the depth and diameter of the recess. Cases may be found where a piece of work like this will actually require a special tool mounted on the turret. For example, if the work were of large diameter and made of high-carbon steel, it might be difficult to machine it in any other way than by means of a single-point tool, in which case something special would need to be designed.

In the example *C* the recess *D* is rather deep and close to the front end of the work. If the diameter of the hole is large, no difficulty will be experienced in machining the groove. If the work is small, however, particular attention must be paid to the design so as to avoid "chatter." In the example *E*, the diameters *F* and *G* are bored and reamed, and the recess is cut at *H*. It is highly desirable to machine this recess in the same setting as that

in which the holes F and G are machined. A piloted bar having a sliding recessing tool in it would probably be necessary for this piece of work.

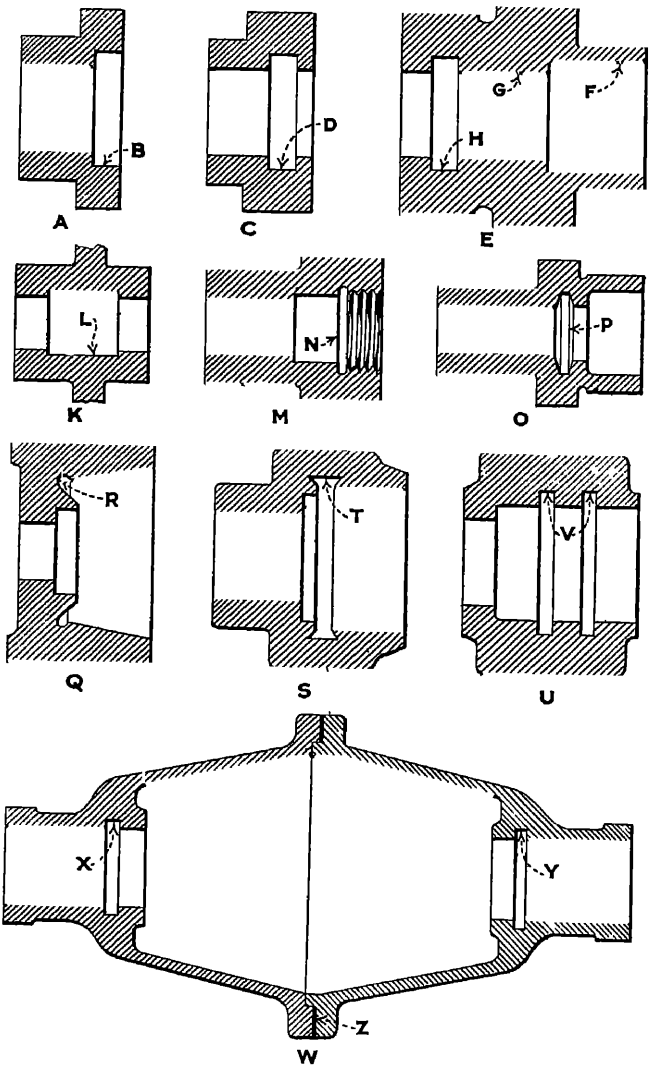


FIG 110 —Work requiring recessing operations

Another condition is seen in the example K, in which the recess L is wide but very shallow. It would not be good practice to

attempt to machine this surface with a tool the full width of the recess. It would be much better to use a boring tool which could be set over sufficiently to give the additional depth required. The turret could then be fed along to bore the diameter *L*, after which the tool could be set back again and removed from the work. The example at *M* shows a very common type of recess at *N*, the purpose of this groove being to allow clearance when cutting the threads indicated. No great accuracy is required for work of this kind, and any of the simpler types of tools can be used. In the case *O* an angular recess is cut at *P*, this groove being used for packing. Its dimensions are not, therefore, of the greatest importance, except that the depth should be approximately correct. The angular portion does not require great accuracy.

The work shown at *Q* has a recess cut at *R* at 45 deg. to the center line of the work. The purpose of this relief is to allow clearance for the tools used in finishing the tapered surface. It is only necessary to provide sufficient clearance for this purpose and the angularity is not particularly important. The work shown at *S* has a dovetailed groove at *T*. This is a very difficult piece of work, as the tool must be first fed in to the proper depth and then carried longitudinally backwards and forwards to remove the angular portion. Two methods are in use for work of this kind. The tool may be shaped to the form of the dovetail but narrow enough so that it will cut a little smaller than the narrowest width of the groove, then the tool can be fed backwards and forwards to produce the angle. The other way is to use two recessing tools, one of which cuts a square groove and the other machines the dovetail.

In the example *U* there are two recesses placed close together as shown at *V*. There is no particular difficulty in machining work of this sort, but it may be done in two ways: either by a single tool with adjustable stops or by two tools at the same time. A simple type of recessing tool will give good results if each groove is handled separately, but a special form will be necessary if both are done at one time.

In the example *W* there are two parts of a housing, and in each of these parts there is a recess, as shown at *X* and *Y*. The two halves are bolted together, with a gasket at *Z*, and the recesses are cut after assembly. There is a large hole in one side of the housing so that the tools are easily accessible. The

spacing between the two recesses X and Y is very important, and in order to insure accuracy, a special finishing tool which cuts both recesses at the same time was found to be necessary.

Simple Recessing Tools.—In considering the design of tools for recessing work, we shall take up the simplest forms first. Several of them are shown in Fig. 111. The work A has a recess at B close to the end of the work. The piece is held in chuck jaws, and a special holder C is mounted on the turret of the

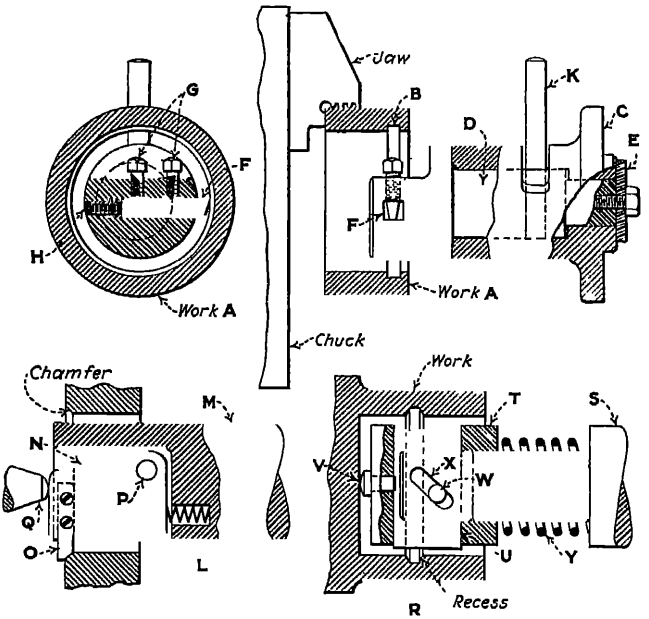


FIG 111.—Simple recessing tools.

machine. This holder has a hole D in which the eccentric stem of the toolhead is carried. The stem is a running fit in the hole and is held in place by means of a nut and washer at E. The end of the toolhead is provided with a cutter at F, held in place by two setscrews at G, as shown in the cross-sectional view. Accurate adjustments are provided by means of the backing-up screw at H. This tool is designed to be fed by hand by means of the lever K, and suitable stops are provided to limit the movement, the stops being made adjustable if required.

It is sometimes necessary to chamfer the rear end of a hole, and the tool shown at L is designed for this purpose. It is auto-

matic in its action, and is not intended to do anything more than break the inside corner of the hole. A tool of similar kind can be furnished with a cutter, to cut a recess when great accuracy is not required. The bar *M* is slotted at the end for a block *N*, which holds the cutter *O*. The block is pivoted at *P*, and provided with a coil spring to keep the cutter away from the work when not in use. A stop pin is inserted in the face of the chuck or faceplate, as shown at *Q*, and the cutter block *N* strikes this stop pin as the turret is moved forward, thus causing the tool to pivot and "break the corner," as indicated. The pivot point *P* must be far enough off center so that the pressure applied will cause the block to move easily. Applications of a tool like this can be made for many operations which do not require great accuracy.

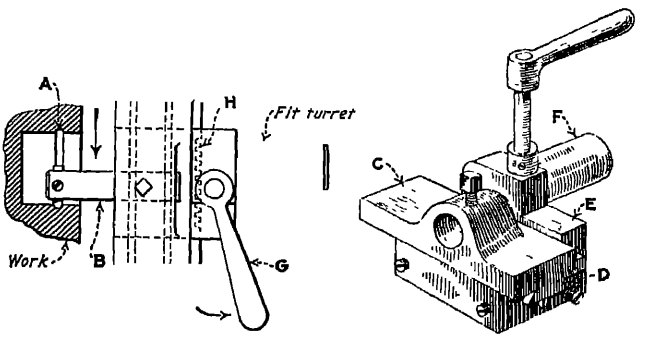


FIG. 112.—Recessing tool with dovetail slide.

Another simple form of a recessing tool which is likewise automatic in its action is shown at *R*. The bar *S* is mounted in some convenient way in a holder on the turret. The sliding collar *T* is slotted to receive the toolblock *U*. The end of the collar has in it a stop pin *V*, which strikes the bottom of the hole and gives the correct location. The toolblock has a pin at *W*, and the bar is slotted on an angle at *X*. When the tool is moved forward, the stop pin *V* strikes the bottom of the hole and the collar remains in position while the bar continues to move forward, thus compressing the coil spring *Y*, which holds the collar firmly against the bottom of the hole. The slot in the bar causes the tool to move outward radially and gradually cuts the recess. After the cut has been finished, the coil spring causes the tool to recede from the groove, so that it comes out of the work freely and without interference.

Applications of this same principle are frequently made on recessing tools. Care must be taken not to make the angle of the slot too great, as too much friction might be caused and the tool would fail to operate. In some cases it may be better to slot the tool block, while in others the bar itself may be slotted. The end of the collar may be provided with a revolving bushing of approximately the diameter of the work, to assist in supporting the tool when cutting a recess in a deep hole.

In Fig. 112 is illustrated an application of a form of recessing tool having a sliding member operated by a rack and pinion. The work has a recess *A* which is cut by means of a tool in the bar *B*. The bar is mounted in a sliding member *C*, dovetailed and gibbed at *D*. The body of the tool *E* has a shank *F*, which fits the turret. An adjustable stop is provided, so that the depth of the recess can be controlled. The operation is by means of a handle *G*, which moves a pinion meshing with a rack *H* on the side of the slide. Tools of this kind are useful for light cutting operations, and they may be standardized in such a way that they will cover a considerable range of work. It is only necessary to provide a bar and a suitable tool for any piece of work within the capacity of the device.

Cam-Operated Recessing Tool.—In Fig. 113 is shown a very good type of recessing tool which can be made cheaply and adapted to various kinds of recessing work. The body of the tool *A* is of cast iron, well ribbed up as indicated and fastened to the turret face. To this body a dovetailed slide *B* is fitted. A tapered gib, shown at *C*, is provided for adjustment. The sliding member contains a lug at *D* in which the tool *E* is held by means of setscrews, shown at *F*. The operation of the device is by means of a handle *G*, which revolves the cam *H*. This part acts against hardened plates at *K* and *L*, thus controlling the movement of the slide. Adjustment for depth is obtained by setting the screw *M*.

This tool is easily operated, and can be adapted to shallow recessing cuts which are close to the end of the work. By using a special design of tool, considerable latitude is possible. A design of this sort can be made with a considerable overhang from the turret if the tool is placed in the other side of the holder, so that the cutting action is downward instead of upward. A support can be provided on the cross slide or the ways of the machine to assist in taking the thrust of the cut, thus making the mechanism

considerably more rigid and capable of handling a heavier class of work.

The work shown at *A* in Fig. 114 has a recess cut deeply in it a considerable distance from the face. This piece can be cut very satisfactorily by use of the cross slide for support and feed. In the example shown, the work has been faced by tools on the front of the cross slide, and there are other tools in the turret previously

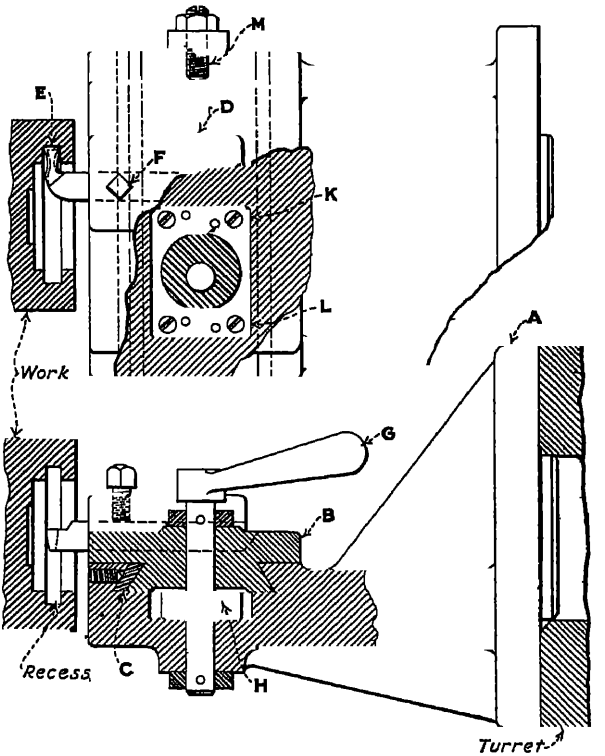


FIG 113 —Cam-operated recessing tool.

used for boring the hole. The recessing tool is simple in design, it works easily and produces excellent results. The turret is equipped with a casting *B* on which a dovetail is cut, as shown at *C*. The bar *D* is held on a sliding member *E*, which is fitted to the dovetail and provided with a tapered gib to permit adjustment for wear.

The cutter for the recess is shown at *F*, being of suitable shape for the form of the recess and being fitted to the bar *D*. Adjust-

ment is provided by means of a backing-up screw in the ordinary way. The member *B* which fits the turret has a lug on it in which a setscrew is arranged at *G*, which allows a setting to be made so that the bar will clear the work when passing in and out of the hole. The bar extends a considerable distance from the face of the turret, and would undoubtedly "chatter" if unsupported.

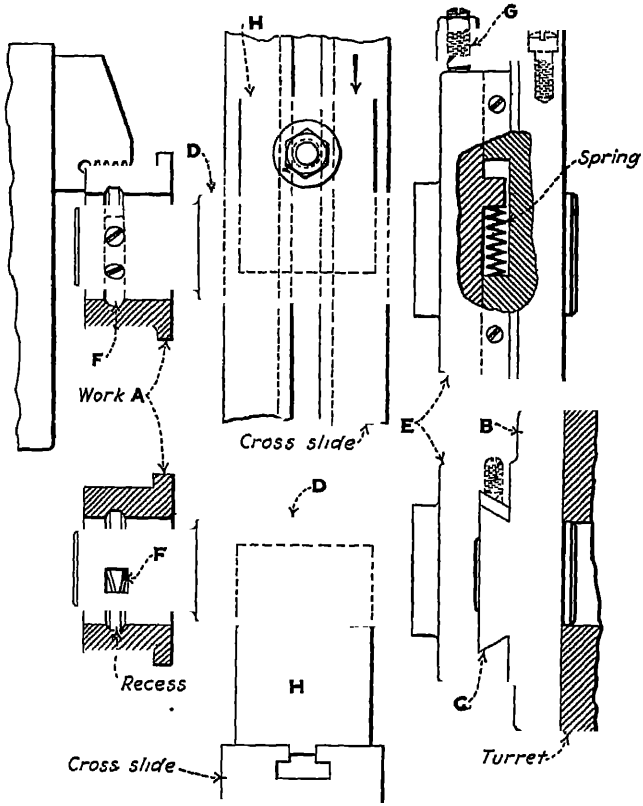


Fig 114.—Recessing tool operated by cross-slide.

Therefore a special block *H* is placed on the rear of the cross slide, as indicated. This block is cut out in *L*-shape and on it the bar is supported. The operator brings up the turret and enters the tool ready for work, the correct distance from the face being determined by the turret stops. The cross slide is then moved in the direction of the arrow until the bar rests on the block, after which slow hand feed is used to force the tool in to the correct

depth. A stiff coil spring between the fixed member and the slide causes the latter to recede after the recess has been cut and the pressure removed.

An opportunity is often found for using a tool of this kind, particularly when it is desirable to use the cross slide in connection with other turret tools. It is possible to design it in such a way that tools may be used at both front and rear slides, although the method of support may be slightly different from that shown, depending on the work.

For certain kinds of light recessing work, slide tools of various

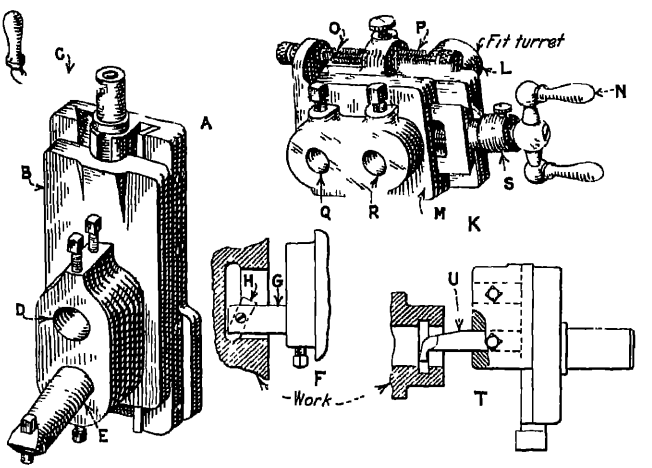


FIG 115.—Varieties of slide tools.

kinds are used successfully. Several of them are shown in Fig. 115. The example at *A* is designed so that it can be attached to the turret of the lathe, and the slide stands in a vertical position. The body of the tool *A* is cut out in dovetail form, and the slide *B* is moved upon it vertically by means of a screw operated by the handle *C*. The slide is provided with two holes at *D* and *E*, in which bars can be placed with cutters suitable to the nature of the work. The slide is capable of adjustment, and the two holes allow for considerable latitude in tool position. For undercutting, back-chamfering on shallow work, and cutting recesses this type of tool will be found very useful. An application to a recess is shown at *F*, a short bar *G* being used with a cutter at *H*.

Another type of slide tool operating in a horizontal plane is shown at *K*. This example has a stem *L* which fits the turret

hole. The casting is dovetailed to receive the slide *M*, which is operated by means of a ball-crank *N*. Adjustable stops are provided at *O* and *P*, so that the depth of cut can be regulated accurately. The slide has two holes at *Q* and *R*, and in either or both of these, tools can be placed for recessing or chamfering. A micrometer collar is applied at *S*, so that accurate readings can be obtained. An application of this device is shown at *T*, a special tool *U* being used for the work. This type of tool is not capable of adjustment, and the size is soon lost in grinding, but for work coming through in small lots it will be found sufficiently good for the purpose.

The matter of gibbing should be carefully attended to in the design of any form of slide tool, in order that adjustment may be provided in the event of wear. A tapered gib is one of the best forms for this class of tool, although it is somewhat more difficult to fit. The adjustment, however, is easy and it is very little trouble to take up wear.

Cutting a Deep Recess.—Mention has been made of the desirability of making recessing tools without spring, so that their action is positive. It is not always possible, however, to do this and yet a little ingenuity will often enable the designer to do away with springs and operate the tool by positive mechanical movements. A difficult operation in recessing is shown in Fig. 116, in which the work *A* is a long cast-iron sleeve having a recess cut in it at *B*, a considerable distance from the face of the work *C*. An accurate job was required, not only as to the depth and width of the recess, but also in its position from the face of the work. The design of the tool is one that can be applied to many other recessing operations in more or less modified form.

The bracket *D* is located on the turret and fastened to it by means of screws. The cylindrical portion *E* is bored out through its entire length. It is fitted with a pilot at the forward end *F*, and the pilot is guided in a bushing in the chuck, as shown. The bar *G* is carefully fitted to the hole in the long cylindrical sleeve, so that it can be moved freely in a longitudinal direction. It is cut away at *H* and slotted on a 30-deg. angle at *K*. The tool-block *L* is fitted with an angular tongue which engages with the slot on the bar. The recessing tool is held in the block by means of a screw at *M*, and adjustment is provided by means of a headless setscrew at *N*. The block slides freely through a rectangular slot cut in the outside sleeve.

A rack *O* is fitted to the rear end of the bar, as shown, and the pinion *P* engaging with it is used to move the bar forward or backward, as may be required. The pinion is mounted on a shaft *Q*, at the upper end of which there is a graduated handwheel *R*. Accurate readings can be obtained by noting the position of the indicator point *S* in relation to the graduations on the wheel. The movement of the block carrying the cutter is positive in its action, and is controlled by the longitudinal motion of the bar. This is a very excellent type of recessing tool, and it can be depended upon to produce results without chatter, and at the

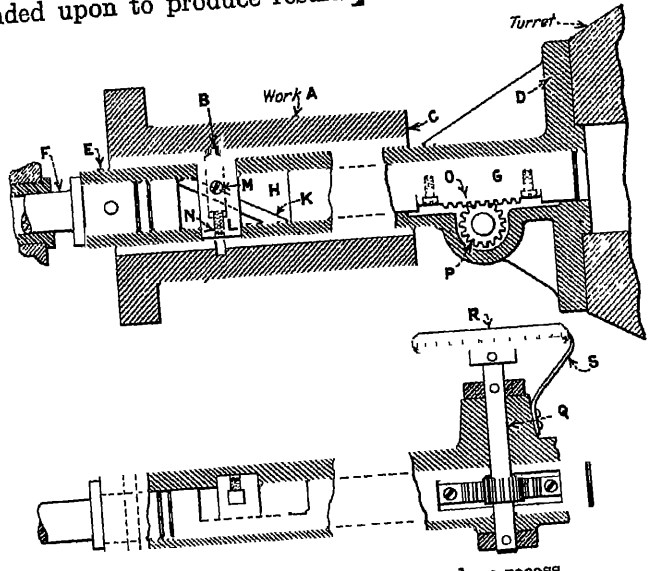


FIG 116.—Tool for cutting a deep recess.

same time rapidly. The exceptional method of support both for the tool and the bar itself gives a rigid construction and permits rapid operation. Care should be taken to provide air holes or vents at any points where there is likely to be a compression of air.

It is easily possible with a design of this kind to cut several recesses at the same time and keep their relations to each other accurately. If a number of recesses were to be cut, it would require only the addition of a suitable number of blocks or a single block with several cutters in it. It would also be possible to cut several recesses in different positions with a single cutter by providing suitable stops to obtain the correct spacing.

Automatic Recessing.—Another type of tool which is automatic in its action and which is adapted for a small variety of work is shown in Fig. 117. In this example the work *A* has a recess cut in it at *B* a considerable distance from the face of the work. The dimension from the face to the recess is important. The casting *C* is bolted to the face of the turret and carries a bar *D*, which is piloted at the other end in a bushing in the chuck. The collar *E* fits the outside of the bar freely, so that the latter will slide through it easily. The tool is contained in a rectangular block *F*, which fits a corresponding slot in the collar *E*. Provision is made to compensate for wearing of the block by the use of two hardened shoes at *G* and *H*, which shoes can readily be removed and set up by means of paper.

The bar *D* has a straight pin in it at *K*, which acts against an angular slot *L* in the tool block, thus controlling the movement of

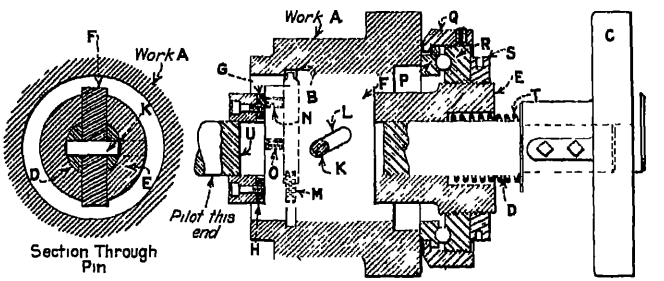


FIG. 117.—Automatic recessing tool for small work.

the tool. Adjustment for the radial position of the tool is made by the setscrew *M*, and the tool is held in place by two headless screws at *N* and *O*. The sectional view through the pin shows the construction quite clearly. The adjustment from the face of the work to the cutter is obtained by the position of the thrust bearing *P*, which is held in place by a threaded collar *Q* on the outside of the adjusting nut *R*. The various depths can be obtained by adjustments of the members *R* and *S*, the latter being used as a locknut. A stiff coil spring *T* forces the collar *E* forward until the front end of the sliding block strikes the edge of the slot at *U*, and when in this position the tool is placed in the work or removed from it.

It will be seen that as the turret moves forward with the tool in position, the pressure against the thrust bearing *P* holds the

entire mechanism in a fixed position with the relation to the work, while the turret carrying the bar *D* continues to travel forward. As it does so, the block *F* is moved outward by the action of the pin *K* in the slot *L*. The depth of the recess can be controlled by an adjustment of the turret stops or by some other convenient means. Unless the depth is particularly important, the turret stop will be found sufficiently accurate.

Recessing tools and those used for back-facing may be somewhat similar in their general construction. It is occasionally

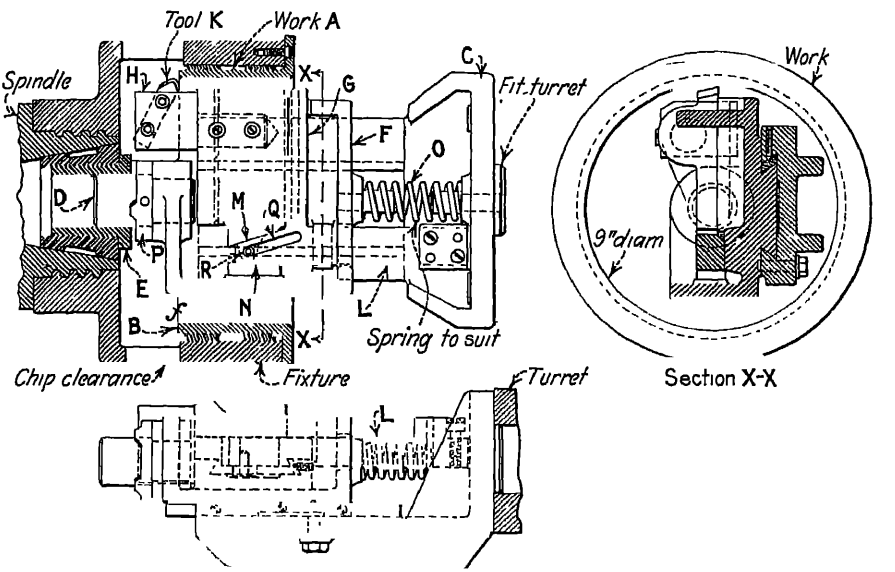


FIG. 118.—Automatic back-facing tool.

necessary to operate a mechanism of this kind automatically, an example being shown in Fig. 118. The work *A* is held in a special fixture mounted on the nose of the spindle. The operation to be done is the back-facing of the surface *B*, and is similar to a recessing job. A cast-iron bracket *C* is fastened to the turret of the machine, and at its forward end a pilot *D* is fitted. This pilot enters the bushing *E* in the spindle of the machine and supports the entire mechanism rigidly.

On the body of the tool a dovetail slide *F* is so mounted that it is free to slide in a longitudinal direction On the upper part of this slide, the member *G* is mounted and dovetailed to fit

another slide. The slide G has a transverse movement, and it carries a bar H, which contains the facing tool K. The bar L is fastened to the turret bracket, and is beveled at the forward end where it comes in contact with the upper slide, as shown at M. It is backed up to take the thrust by the steel block N. The entire mechanism works against the thrust of the heavy coil spring O.

In operation the turret moves forward until the stop collar P strikes against the end of the bushing in the spindle. Continuation of the turret movement causes the bar L to move forward, thus forcing the slide G in a transverse direction and causing the tool K to face the back of the work. The longitudinal slide naturally remains stationary with respect to the work and the turret bracket really travels under it. The coil spring O holds the sliding members F firmly against the bushing and prevents any longitudinal movement of it.

As the return movement of the tool would be dependent upon the pressure of the spring O, considerable trouble might be caused if this spring failed to act when removing the device after the operation. Therefore, as a precautionary measure, the bar L is slotted at Q, so that the backward movement of the turret acts upon the pin R, which is contained in a lug on the slide G. If anything were to happen to the spring, the slot and pin would serve to pull the slide back, so that no trouble would be caused.

In designing tools of this kind, great care must be exercised to make sure that all parts are rigidly supported, and precautions must be taken to guard against trouble which might be caused by the sticking of moving parts. The stop collar P can be provided with a ball thrust bearing, if this is considered desirable. The dovetail sliding members must be furnished with suitable gibs to take up wear.

Double-Acting Tool.—The widths and diameters of recesses are not usually held within very close limits of accuracy, but occasional cases are found where very close tolerances are called for. Such an example is shown in Fig. 119, in which the work A is a cylinder having a recess cut at B in accurate relation to the end of the casting C. Both the depth and width of the recess are important, and it is therefore necessary to design a tool in such a way that these sizes will be machined accurately.

The tool was designed for use on a drilling machine, but the principles illustrated can readily be adapted to tools for use on

other machines such as an engine lathe, turret lathe or boring mill. As originally designed, the bar *D* was arranged to fit a quick-change chuck. In using the recessing tool, this chuck was placed in position in the casting on a drill press, the spindle was brought down upon it and a rapid connection made. A

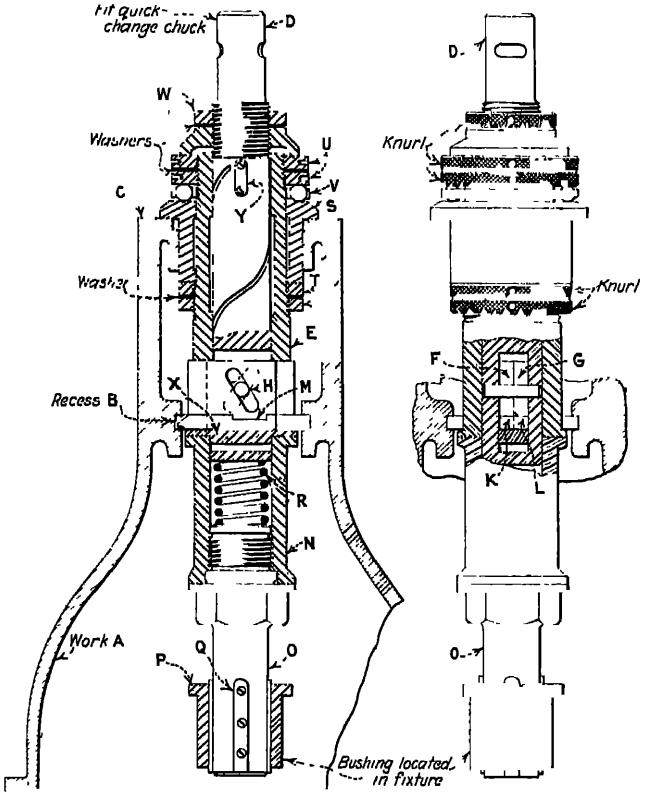


FIG. 119.—Double-acting recessing tool.

sliding type of fixture was employed, in order to avoid very long movements of the drilling machine spindle. The sleeve *E* is a sliding fit on the bar *D*, and both bar and sleeve are slotted to receive the two blocks *F* and *G*, which are controlled and moved readily, but in opposite directions, by means of a pin in the bar and angular slots in the blocks, as shown at *H*. There are two cutters at *K* and *L*, so arranged that each of them cuts one side of the recess, a method employed in order to preserve the width.

These cutters are notched at *M*, so that they engage with the sliding blocks mentioned, thus controlling the movement of the tools. The lower part of the sleeve *N* is threaded and fitted with a pilot *O*, which enters the bushing *P* in the fixture. The end of this pilot bar is provided with four bearing shoes *Q*, ground cylindrically so that they fit the inside of the bushing. The space between them allows clearance for any chips which may work down and get into the bushing. In the normal position, a heavy coil spring *R* presses against the end of the bar *D* and forces it upward, so that it draws the cutters inward and away from the work.

The position of the recess is determined by an adjustment of the stop collar *S*, which rests on the finished face of the casting *C*. Adjustment is made by the locknuts at *T* and *U*. A ball thrust bearing is interposed at *V*, as indicated. When in use there is a slight amount of clearance between the bottom of the bushing *S* and the top of the locknuts *T* and *U*, and the bushing does not revolve during the operation. The depth of the recess is controlled by an adjustment of the stop collar and locknut at *W*. This arrangement gives a freely moving tool and no thrust on the end of the casting, as this thrust is taken up by the bearing at *V*. A hardened and ground seat *X* fits in the slot and takes the pressure of the cutters, to avoid wear on the sleeve itself. Note that the sleeve is driven by two keys *Y*, in order to obviate any torsional stresses on the cutter blocks.

CHAPTER X

REAMERS AND FLOATING HOLDERS

TYPES OF PLAIN AND SOLID REAMERS—CORE DRILLS AND ROSE REAMERS—EXPANSION AND INSERTED-BLADE ADJUSTABLE REAMERS—TAPERED REAMERS FOR ROUGHING AND FINISHING—PRINCIPLES OF FLOATING REAMER HOLDERS FOR TURRET LATHES—PIN-TYPE AND FULL-FLOATING HOLDERS

Reamers of various kinds are used for sizing holes, generally after a boring or drilling operation. The form of reamer used depends on the kind of work and to some extent on the material being cut. The cutting action of a plain reamer occurs at the end only, although there is doubtless a slight scraping action along the flutes. On certain kinds of work provision must be made to counteract this latter effect, as in the case of work which is very thin, where the weight of the reamer in the hole might cause it to cut and enlarge the diameter slightly.

A reamer must be considered not as a generating but as a sizing tool, and the accuracy obtained by its use is dependent upon a number of factors. The design of the reamer is influenced by the size of the hole, the material to be cut and the general conditions connected with the holding and driving of the reamer itself.

The following points are of importance in connection with reamer design:

(1) The diameter of the hole to be reamed has an effect on the design. For a small hole it may be necessary to make a solid reamer, while for a larger hole blades inserted in a body can be used and suitable adjustments provided. The size of the hole controls the number of flutes in the reamer, or the number of inserted blades which are used. The length of the hole which is to be reamed is likely also to affect the design of the reamer to some extent. A reamer used for a long hole may require a pilot, while a short hole can be reamed by means of a plain reamer without a pilot.

(2) The material to be cut affects the design, both as to the number of flutes in the reamer, the angle of the cutting edge, its relief, back taper and the method of support. A reamer may be

straight or tapered; it may have straight or spiral flutes; the teeth may be equally or unequally spaced, according to the material being cut. The teeth on reamers used for steel and cast iron are generally on center, while for brass they are sometimes cut slightly ahead of center. Occasionally square reamers or scrapers are used for fine finishing, particularly when the material is brass. In reaming babbitt metal, the end of the reamer is often ground tapering for about ½ in., the taper starting at the diameter of the hole generated by the boring tool. By using this method a smooth hole free from lines and rings can be made. In order to avoid chatter, left-hand helical fluting is recommended.

(3) The reaming allowance, or the size of the hole into which the reamer enters, is quite important. In certain kinds of materials such as brass and malleable iron, a reamer should have more stock to remove than in steel and cast iron. Unless a sufficient amount is left for the reamer to remove the cutting action is not good, and after the hole has been finished it will shrink and be undersized. When using only one sizing reamer for steel or cast iron, the amount of metal removed varies from 0.005 to 0.015 in., depending somewhat on the diameter.

It must be remembered that the size of the hole in production work depends for its accuracy to a great extent on the finishing reamer having the same amount of stock to remove in each case. Hence, boring tools or other cutting tools used prior to the reamer must be so made that they will leave the hole the same diameter.

A roughing reamer should always be preceded by a single-point boring tool or its equivalent, in order to generate a true hole. On very accurate work, both roughing and finishing reamers can be used. When they pass entirely through the work, it is possible to place both reamers on one bar, although the first reamer should be entirely through cutting before the second one enters the hole.

(4) For convenience in calipering, reamers are usually made with an equal number of teeth. These teeth are spaced an unequal number of degrees apart in order to prevent "chatter." This is a very important matter, as only once in each revolution are all the teeth in duplicate positions. Reamers are often made with left-hand helical flutes, which construction prevents chatter to a certain extent, and at the same time prevents drawing in. This type, however, is much more difficult to grind.

(5) Adjustable reamers possess many desirable features, but there are few, if any, that can be adjusted to cut a given

diameter of hole without grinding the cutting edges each time the adjustment is made. This fact should not, however, be considered as an argument against reamers of this type, as their economy is well known, and it is certainly easier to reset and regrind a reamer than it is to make a new one. There are several types of adjustable and expansion reamers on the market, and they can often be adapted for use with special bars in turret lathe operations.

Reamer Details.—Some of the points of importance in connection with reamer design are brought out in the various diagrams

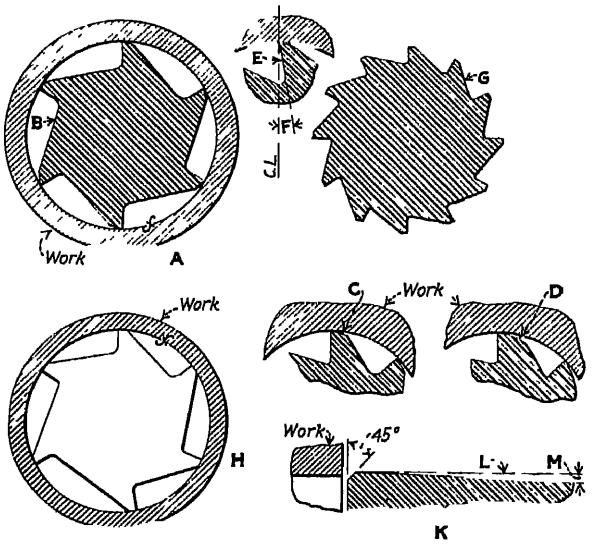


FIG 120.—Details of plain reamers.

shown in Fig. 120. The example at *A* is a sectional view through a reamer *B* and clearly shows the cutting action of the tool. In this example, the reamer is a 6-flute type having flat-relieved teeth, as shown in the detail at *C*. The teeth may be relieved eccentrically, as shown at *D*, and it is claimed that this method of relief gives a somewhat stronger tooth. An additional advantage is that it reams a smoother hole, because there is no chatter. Reamers of this type are sharpened by grinding on the face of the flute; and, as the relief is eccentric, a working size is retained for a longer period than on the flat-relieved type.

In the diagram at *E* the flute is shown in undercut form, as indicated by the angle at *F*. This practice is not generally

followed, the flutes ordinarily being cut either on center or slightly ahead of center, depending upon the material which is to be cut. The number of teeth for a given size of hole must be proportioned according to the diameter of the hole. In the example at *B* there are six flutes, while in the sectional view at *G* twelve flutes are shown. In considering the number necessary, the purpose of the flute must be thought of. First, the flutes are made in order to provide a series of cutting edges; second, they allow space for chips, so that the latter will not roughen the work; third, they allow lubricant to pass between the teeth and assist in the cutting action. The number of teeth, therefore, should be proportioned so that sufficient chip clearance is provided, so that the reamer has sufficient bearing on the inside of the hole to produce a smooth piece of work, and so that there is sufficient depth to the flutes to enable lubricant to readily enter when necessary.

Manufacturers of reamers have established a more or less uniform practice in regard to the number of flutes in reamers to be used for various diameters. The designer can easily ascertain the number of flutes commonly used by reference to a small-tool catalog, and it is advisable to adhere closely to standard practice in this regard. In the example shown at *H*, the teeth of the reamer are spaced unequally in order to prevent chatter.

There are two methods in common use for spacing reamer teeth. One of them is to space all teeth a different number of degrees apart, from one to two degrees being considered a sufficient variation. There is an objection to this method on account of the difficulty of measuring the reamer, but this can be obviated by soldering a piece of brass in one of the flutes against the cutting edge. This piece will be ground with the reamer blades and measurements taken at this point. The other method is to make the teeth on one-half of the reamer unequally spaced, and follow out the same procedure on the other half in such a way that the teeth will be opposite each other.

The teeth of a reamer are usually beveled to about 45 deg. on the front end, as indicated in the diagram at *K*. For steel and cast iron the cylindrical portion of the reamer may be ground straight, as indicated by the line at *L*. For brass work or other soft materials, a slight back taper is often used, as shown at *M*. This construction prevents roughing up the hole, and gives a smoother result.

Different kinds of work require different types of reamers. Several forms are shown in Fig. 121. The example at *A* illustrates a plain type of hand reamer which is not generally used in a machine. It is practically square on the end, and is usually tapered for a part of its length so that it will enter the hole and center itself when in use. The tapered portion may extend from ½ to 1 in. from the end, according to the size of the reamer. Teeth in hand reamers are generally somewhat closer together than those used for machine reaming, as the amount of stock removed is small and chip clearance is not as important.

The tool shown at *B* is sometimes called a four-lip reamer,

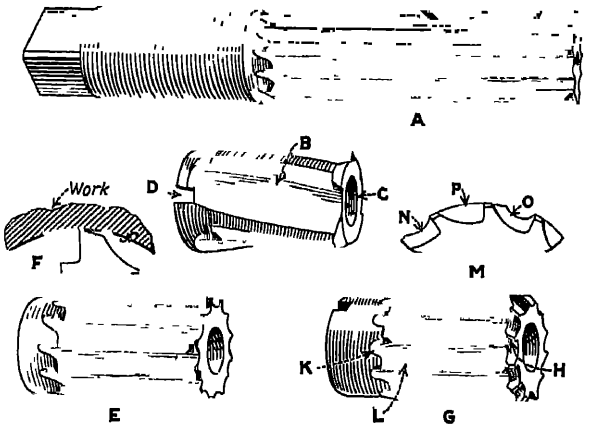


FIG. 121.—Types of solid reamers.

but as generally used, the term "core drill" is more nearly correct. This reamer is of the shell type and has a taper hole at *C*, so that it can be slipped on to a bar and driven by a key or tongue in the slot at *D*. The flutes are cut on a right-hand helix and a considerable amount of chip clearance is provided. In removing the stock from a cored hole, this tool is useful, but it is not intended to ream a hole accurately, although with careful usage very good results can be obtained by it. When properly used, it is preceded by a boring tool so as to generate a true hole for a short distance.

The example shown at *E* is a plain shell reamer designed to be slipped on a bar and driven by a pin or key. This form of reamer is commonly used for many kinds of sizing operations on turret lathes and other machines. The flutes may be either straight

or helical, but if the latter, they are usually milled on a left-hand helix of long lead. Helical reamers are less likely to chatter than those which are straight, but they are much more difficult to grind and, therefore, are not used as frequently as those having straight flutes.

The cutting action of a reamer of the sort shown is on the end only, as previously mentioned. If ground properly, there should be no great danger of cutting holes which are oversize; but as there are several conditions to contend with, certain classes of work may require another type of reamer in order to preserve the sizes accurately. The diagram at *F* shows the position of the teeth in relation to the inside of the hole; and it is apparent that there is a possibility of a scraping action being produced here, which will naturally enlarge the hole slightly.

The "rose" type of reamer can be used on thin work when the hole must be held closely to size. An example of this variety is shown at *G*. The distinguishing difference between a rose reamer and a plain shell reamer is in the cutting of the flutes. In the rose reamer there are, strictly speaking, no flutes, but rather grooves through which lubricant and chips can be carried. The purpose of a rose reamer is to provide a tool which will positively cut only on the end, and which will obtain a cylindrical bearing inside the hole, without the possibility of any scraping or cutting action on the edges of the flutes.

Rose reamers are made in several ways, but their essential principles are the same. In the example at *G* the cutting lips at *H* are made at an angle of 45 deg. with the end of the reamer, and they extend back only a short distance. Shallow grooves are cut as indicated at *K*, these grooves being somewhat narrow so as to allow a land *L*, which acts as a bearing on the work between the grooves. In some cases, teeth are cut on the end of a rose reamer and grooves are provided at every alternate tooth only, instead of making them at every tooth.

The enlarged view at *M* illustrates the appearance of the end of the reamer when cut in this fashion. The grooves at *N* and *O* extend along the length of the reamer, but the portion *P* is solid and is cut away only at the end, as previously mentioned. The cylindrical surface of the body part is not relieved at all, but it is slightly back tapered. This taper should not exceed 0.001 in. per inch of length. Due to its cutting action, the rose reamer is likely to produce a hole slightly larger than the actual

diameter of the reamer, and for this reason it is usually ground a trifle smaller than the hole for which it is intended.

Expansion reamers are useful for cases when a hole very slightly larger than standard is to be reamed. In assembly work, when parts fit a trifle too closely this type of reamer is often used to remove a very small amount of metal, thus providing sufficient clearance in the hole. Ordinarily they are not considered as production tools, because the adjustment permissible is very small, and they are otherwise unsuitable. Fig. 122 illustrates several types of expansion reamers. They are usually hand

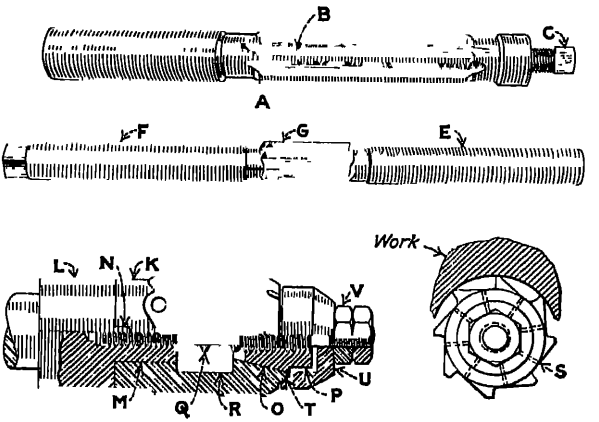


FIG. 122 —Types of expansion reamers.

operated, but it is possible to utilize them in connection with a holder, if this is found desirable.

In the example *A* several slots *B* are cut by means of a saw between the flutes of the reamer, in order to provide for a small amount of expansion. A taper plug which acts upon an angular surface at the center of the blade is controlled by movement of the screw *C*. By means of this screw the plug can be adjusted so that it will expand the diameter of the blades a few thousandths of an inch. Reamers of this kind may be made long and piloted at each end, as shown at *D*. When used in this way, the portion *E* is made to the diameter of the hole as it is before reaming, while that at *F* is proportioned to the size of the expanded part in the middle. For use in aligning two holes which are separated, reamers of this kind can be used. The method of expanding the portion *G* is similar to that previously described.

Various adaptations of these forms of expansion reamers can be made, the conditions under which they are used governing the design to some extent. It must always be remembered that the latitude of these tools is very small and that they should not be used in place of adjustable reamers except in cases of emergency.

Another type of expansion reamer having considerably more latitude than those previously described is shown at *H*. In this example the reamer body *K* is adapted for attachment to a shank *L*, so that it can be used for production work. The body is of shell form, as shown in the sectional view. It is fitted to the pilot *M* and driven by means of a tongue and slot, as shown at *N*. The front end of the reamer is bored out to a taper at *O*. In this taper the conical plug *P* is carefully fitted. A stud *Q* extends through the hollow center of the reamer and is screwed into the holder.

The body of the reamer is relieved at *R* and split between each of the flutes, as shown in the end view at *S*. This is done to permit easy expansion. The end of the reamer is tapered at *T*, and a collar *U* fits over this taper. In adjusting the reamer for a given diameter, the collar and the two nuts at *V* are removed. The taper plug *P* is then screwed up by means of a spanner wrench until the proper diameter has been reached, after which the collar *U* is replaced and the nuts *V* set up and locked. This type of expansion reamer is capable of considerably greater adjustment than the others described, and may be used occasionally for manufacturing or production work.

Adjustable Reamers.—A solid reamer after it has been worn must be reground and used for a smaller diameter. Reamers with inserted blades, however, can be adjusted and reground to the same diameter for which they were originally made. Hence, this type of reamer is to be preferred on account of its upkeep, although the first cost may be slightly greater than the solid type of reamer.

Adjustments of inserted blades may be made in several ways. A very economical type is shown in Fig. 123 at *A*. The body of this tool *B* may be made up in any form, either as a part of a bar or as a shell like that indicated. In the latter case, it can be applied to a suitable bar and driven by means of the slot at *C*. The cutter blades shown at *D* are inserted in slots cut in the body of the tool at *E*. They are held in place by means of the screws *F*. A pin is provided at *G* to take the thrust, so that it will not

be carried by the screws. When a tool of this sort is made, the blades are placed in position and firmly secured, after which the reamer is ground in the regular way. After they become worn, the blades are removed and paper or metal "shims" are inserted under the blades, which are replaced and reground to the right diameter.

Blades may be cut straight or helical, according to the require-

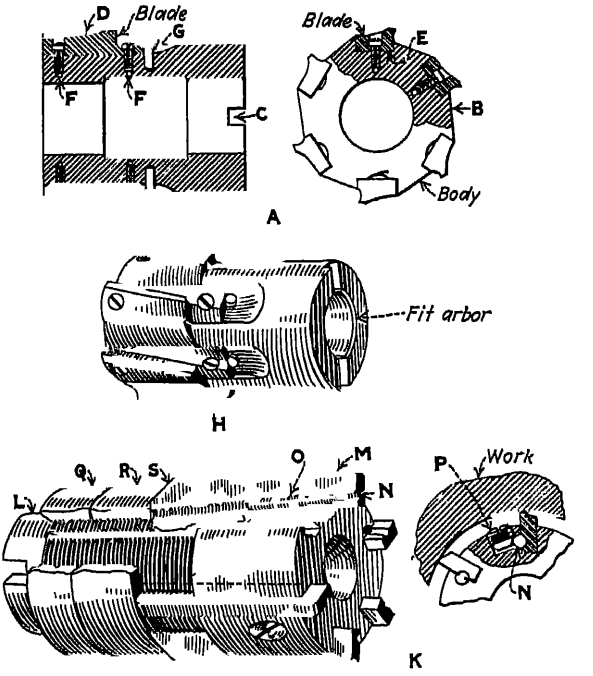


FIG. 123.—Typical adjustable reamers.

ments. An assembled view of a reamer of this type having helical flutes is shown at *H*. The advantages of this construction are the facts that the blades and bodies can be standardized and made up in quantity, the up-keep of the tool is excellent, and the cost is not excessive. Shims of various thicknesses, either of paper or metal, can be made up so that they can be slipped in when needed.

Another type of adjustable reamer is shown at *K*. In this example, the body of the tool *L* is of standardized shell form having an internal taper which fits a standard shell reamer arbor.

Slots are cut in the outside of the body to receive the blades *M*. The slots are back tapered and the blades fit them accurately. On one side of each blade is a groove *N*, and in this groove a round hardened pin *O* is placed. This pin is forced over into the groove by means of the screw at *P*. The action not only tends to hold the blade down firmly, but also throws it over against the solid portion of the body, thus making a very rigid construction.

Adjustment is provided by means of the two collars at *Q* and *R*. The collar *R* is undercut at *S*, so that it fits over the beveled

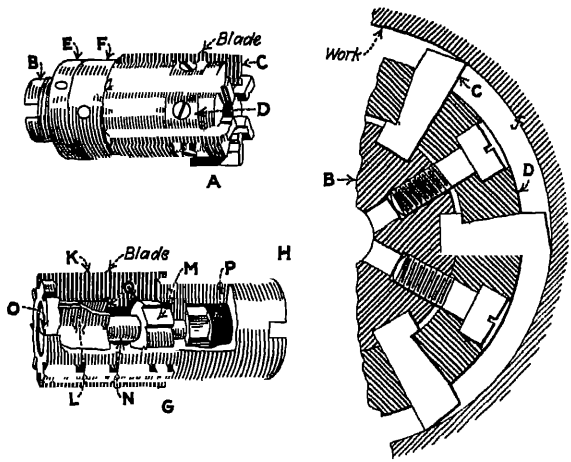


FIG. 124.—Other adjustable reamers.

end of the blade and assists in holding down this end. The collars are set up in making an adjustment, thus carrying the blades of the reamer forward and at the same time outward. After this is done, the blades can be reground if desired. A decided advantage in this type of reamer is the fact that the blades move forward and are ahead of the body of the tool. There are no other projecting parts to catch chips or cause trouble. The blades always cut clean to the bottom of the hole.

In Fig. 124 are shown two other reamers of the adjustable type. In the example *A*, the body *B* is of shell form standardized to fit shell reamer arbors. Slots are cut in the body to receive the blades *C*. The method of holding the blades is by means of shoes shown at *D*, these being set in an annular groove around the body of the reamer. Their action when set up tends to pull

the blades firmly down into their seats, and at the same time carry them over against the solid portion of the body. The construction is clearly shown in the large sectional view. Adjustment is obtained by means of the two locknuts at *E* and *F*, the latter being cut out in angular form so that it fits over the beveled end of the blade. The slots which receive the blades in this reamer are tapered toward the front end, so that smaller diameters are obtained by moving the blades forward and larger diameters by moving them backward. After setting, blades can be ground to diameter if desired.

Another type of adjustable blade reamer is shown at *G*. In this variety, the body *H* contains a number of slots which hold the blades indicated at *K*. These blades bear solidly on the hardened and ground cam faces at *L* and *M*. In adjusting the blades, the cam bolt *N* is revolved by means of the slot in the end, shown at *O*. This causes all the cams to act equally on both ends of all cutter blades. When the desired diameter is reached, the locknut *P* is tightened with a special socket wrench. The angular lug on each blade is acted upon by the undercut portion of the cam bolt, as shown at *Q*. After tightening the locknut *P* the reamer is ready for use, or it can be reground if desired.

Adjustable reamers can be set without regrinding in some cases, but it is usually found advisable when great accuracy is required to set slightly larger than the required diameter and regrind to exact micrometer sizes. The various types of adjustable reamers shown here are thoroughly practical and extremely useful for production work. They are economical in use, and new blades can be purchased from time to time after the old ones have become worn to the maximum permissible amount.

Before reaming a tapered hole, it is necessary to provide a true-running hole. To accomplish the latter, it is advisable first to bore straight several steps of the taper. On very shallow tapers it is obvious that the hole should be bored straight, entirely through the work, but on tapers having considerable angle and on large sizes, the method first suggested will be found of advantage. There is considerable trouble caused by "chatter" when using taper reamers, and it is advisable to look into the reason for this so as to counteract it in the design.

A Common Form of Chatter.—The most common form of chatter when reaming a tapered hole is that caused by the reamer

tending to pull into the hole. If the tool works to one side, it has different amounts of material to remove on opposite sides, so that it cuts unequally. The consequence is that it either breaks or starts to chatter. If it is possible to pilot a tapered reamer this is a great advantage; but it cannot always be done. If considerable stock is to be removed from the hole, as in the case of a rather abrupt taper, it is well to use several tools in the hole. The first tool should be a boring tool having several cutters, which will generate two or three steps of the taper. The second tool can be a taper roughing reamer of the form shown at *A* in Fig. 125.

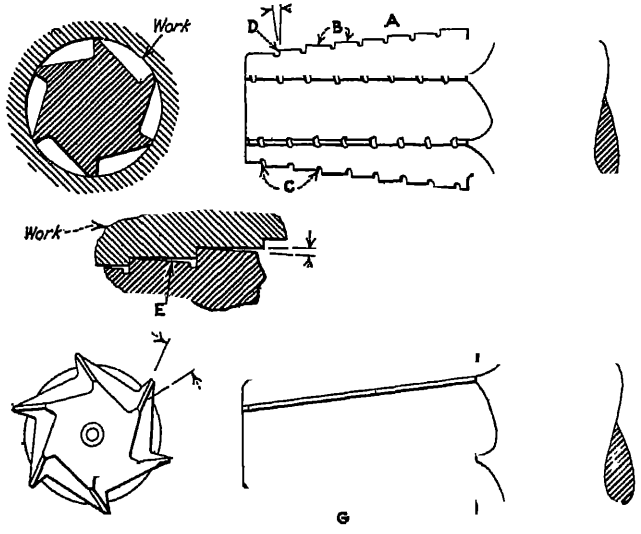


FIG. 125.—Roughing and finishing taper reamers.

The design of tools for roughing out taper holes is controlled to a great extent by the angularity of the taper, and the condition of the hole before it is reamed. Assuming that a given piece of work has been previously bored, as mentioned, and that all scale has been removed from the inside, the tool *A* can be made up with three or more lips, the number depending upon the size of the hole.

For comparatively small sizes three lips are sufficient, and there is a distinct gain in the cutting action, because the stock is removed much more easily and with less pressure. For large diameters more lips can be used, but a general principle is to

use as few flutes in a roughing tapered reamer as possible. Many times lubricant is necessary, and deep wide flutes allow it to enter readily and permit the chips to be washed out freely. For abrupt tapers the roughing reamer can be made with a right-hand helix, but for shallow tapers it should be straight or with a slight left-hand helix, in order to prevent "drawing in." For roughing out the hole the taper reamer should first be formed, and after this it should be broken up into a series of steps *B*. A groove having a lead of from ¼ to ½ in. should be cut at the end of each step, as shown at *C*. The steps and groove can be considered helical in form if the taper be disregarded, although they resemble a spiral when the taper is viewed from the small end. This groove allows cutting teeth to be formed, as indicated at *D*. Each of the steps should be back tapered slightly in order to permit free cutting. This is illustrated clearly in the enlarged detail at *E*. If the groove *D* is cut on a right-hand helix, it will automatically relieve the ends of the teeth, so that they will cut freely. The teeth should be relieved eccentrically on a relieving attachment and then hardened, after which the flutes may be ground to give a cutting edge.

The finishing taper reamer shown at *G* usually has more flutes than the roughing reamer. The flutes may be straight or with a left-hand helix angle, but never with a right-hand angle, as this would cause the reamer to draw in and chatter. In reaming steel, a narrow helical groove can be cut with a lead of ¼ in. or so, the entire length of the reamer. When this is done, one tooth overlaps the other and no grooves are apparent in the finished work. At the same time, the chips are removed much more easily, because the cutting action is considerably improved. On very long surfaces, this groove will be found to assist materially in making the cutting action easier.

Floating Reamer Holders.—When holes are reamed by hand, the reamer naturally follows the generated hole; but when held rigidly in a machine, improper alignment may cause the reamer to cut oversize or otherwise incorrect holes. Some of the causes of failure of reamers to cut true to size can be attributed to the method of holding the reamers, while others may be due to an incorrectly generated hole or one which does not allow sufficient stock for the reamer to remove. A great deal depends upon the way in which the work is held, and the preliminary work which has been done in the hole before reaming.

We shall consider the application of floating holders to turret-lathe work, and the reasons which make it necessary to use holders of the floating variety. Fig. 126 shows a piece of work *A* which is to be sized by the reamer *B*. The latter is held rigidly in a holder *C* fastened to the face of the turret. We shall assume that the hole in the work *A* has been generated, so that it is true with the center of rotation of the work. If then, every part of the machine is in perfect alignment, and if the reamer is located

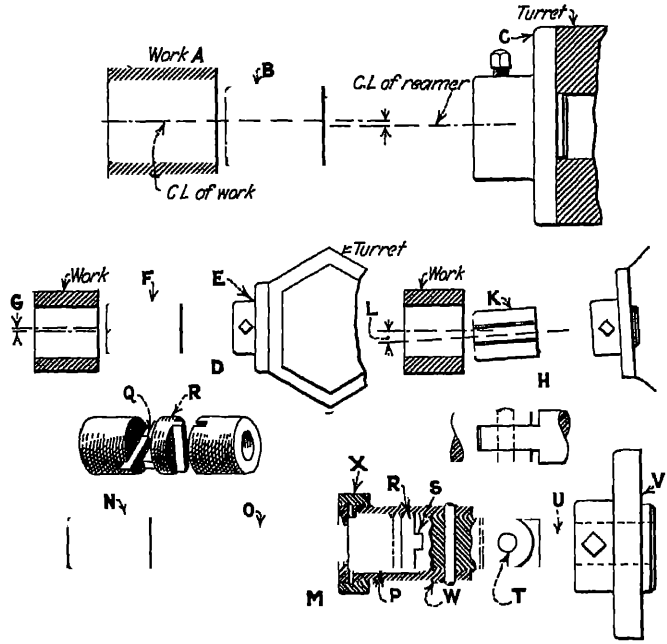


FIG 126.—Principles of floating reamer holders.

directly on the center line of rotation, the hole should be of correct size after reaming.

In actual practice it seldom happens that all parts of a machine are in perfect alignment, and therefore the reamer would be more apt to cut unequally if held rigidly in the holder as shown. If the turret has been used considerably the center line of the holder is likely to be several thousandths of an inch below the center of the work, which would naturally cause the reamer to take a position, as shown, considerably below the center line. The result would be an over-size hole if the reamer were to be held rigidly. This condition is frequently found in turret lathe work.

Less common is the condition shown at *D*, in which the center line of the holder and work do not correspond, due to an inaccurate setting of the holder *E* on the face of the turret, so that the reamer *F* is off center on one side an amount indicated between the arrows at *G*. The hole would also be over-size if reamed in a rigid holder under these conditions. The example at *H* shows a turret which does not index correctly on account of considerable abuse or overhauling by unskilled labor. In this case, the reamer would take the position shown at *K*, and the result here would also be an over-sized hole. The angularity between the center line of the work and the center of the reamer is shown at *L*.

Of the three conditions, the most common is that shown at *A*, in which the turret slide has been worn by use so that the center line of the turret is slightly lower than the center of the work. In order to counteract all the conditions just mentioned, it is necessary to hold a reamer in some type of "floating holder," so that it can automatically align itself with the center line of rotation and follow the generated hole correctly. In theory, a holder must be devised for this purpose which will permit the reamer to float in all directions.

An example of a holder intended to provide this floating is shown at *M*. The reamer *N* is mounted on a shank *O* which is enlarged at *P* and slotted on the end, as shown in the detail at *Q*. The member *R* has tongues on both sides at right-angles to each other, so that it freely fits the slot *Q* and another slot in the member *S*. The latter member is pivoted at *T* so that it will swing freely. The shank *U* is held in a holder at *V*, which is fastened to the turret. Excess movement of the reamer is prevented by a small amount of clearance in the restraining collar *W*, which is pinned to the member *S*. The reamer is prevented from pulling out by an adjustable threaded sleeve *X*. A holder based on this principle will allow the reamer to float in any direction and align itself with the center of rotation of the work. This particular example is not intended to show anything more than the principles which are involved in the construction of a true floating reamer holder. It can be modified and developed to suit a particular case if desired.

Pin-Type Holders.—Many writers have discussed methods of obtaining a true floating reamer holder. While we do not wish to differ from many of the statements made on the subject, we shall simply state that there are many cases when a very simple type

of holder which is theoretically incorrect, will produce a commercially true hole of a diameter determined by the size of the reamer. This is largely due to the fact that the error in alignment between the turret and the work is usually in an up and down direction, so that a float in this direction will take care of the majority of cases. Fig. 127 shows in simple form several types of floating reamer holders. Many of them are more or less objectionable from the standpoint of theory, but at the same time they are often used successfully.

In the example at *A*, the shank of the reamer *B* has a pin *C*

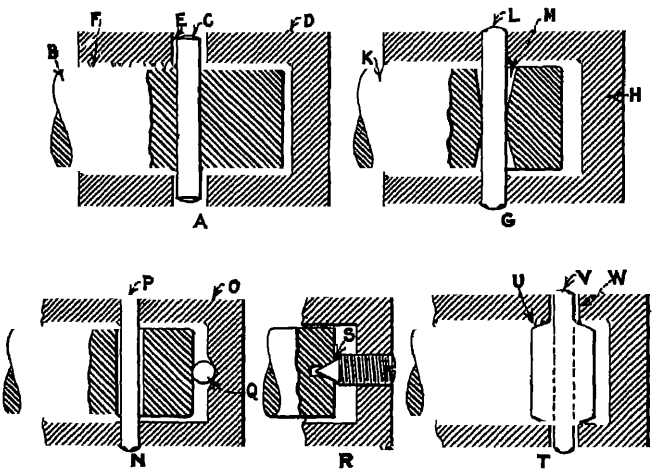


FIG. 127.—Simple types of floating reamer holders

driven through it. The holder *D* is located in the turret by some convenient method. A hole *E* in the holder is made slightly larger than the pin, and the shank *E* is somewhat smaller than the hole *F* in the holder. By this means the shank is permitted to float up and down freely, and a certain amount of side motion is also permissible. Furthermore, the shank rocks on the pin so as to take care of slight angular errors. This holder is not theoretically correct, as will be shown later, and yet it is a type very commonly used in many shops and producing more or less satisfactory results.

The example shown at *G* consists of a holder *H* of suitable size to fit the turret of the machine. The shank of the reamer shown at *K* is slightly smaller than the hole in the holder. The pin *L* is a driving fit in the holder itself. A hole through the

reamer shank is countersunk on both sides and tapered, as shown at *M*. The center of the hole fits the pin snugly. The theory of this type of holder is that a slight spring or rocking action will take place when the reamer enters the generated hole in the work. The reamer may move up and down slightly on the pin. Although not strictly correct in theory, this holder is simple and very fair results can be obtained by its use.

Another example is shown at *N*, in which the holder *O* has a

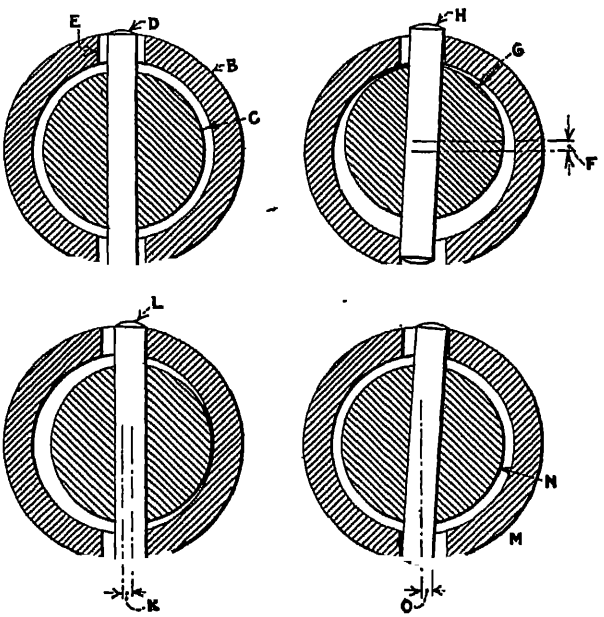


FIG. 128.—Action of pin-type floating holders.

pin *P* driven through it. The reamer shank is drilled slightly larger than the diameter of the pin, and the thrust on the reamer is taken by the ball *Q* which rests in a countersunk hole in the holder. This method of holding permits the reamer to float up and down, while a certain amount of angular movement is also allowed. In the example *R* a center *S* is used in the end of the reamer shank. This method is objectionable, as it centers the reamer and does not allow it to parallel itself to the generated hole in the work.

A very old type of floating reamer holder is shown at *T*. Many factories use something of this kind as a floating reamer holder,

but it is open to numerous objections. The shank of the reamer is turned in spherical form at *U* to a diameter slightly smaller than the inside of the holder. The pin *V* is used as a driver, and is allowed to float in the oversize hole *W*. If sufficient clearance is provided between the spherical end *U* and the inside hole, this type of holder can be made to produce very good results. If the turret is considerably out of alignment, however, and there is only a small amount of clearance in the hole, the reamed hole is likely to be "bell-mouthed."

The diagram shown in Fig. 128 illustrates the reasons why a reamer using a pin driver does not always work out as satisfactorily as it should. In the first example a sectional view of the holder is shown at *B*. The reamer shank *C* has a pin driven through it at *D*, and clearance is provided for this pin in the hole *E*. If the center of the reamer holder is slightly below the center of the work, as shown at *F*, the shank of the reamer will float until it takes a position like that shown at *G*, and the pin will drive against both sides of the hole. The reamer, however, will find the center of the generated hole without difficulty, as is shown by the fact that the center line of the pin *H* crosses that of the holder.

If we assume another condition in which the turret hole is off center an amount shown at *K*, the driving pin *L* must take a position like that shown in order to have the reamer parallel itself to the hole. This is all very nice as far as it goes, but the moment that the pressure of the cut is applied under a condition of this sort, the pin immediately is thrust over and acts as a driver against the two sides of the hole, as shown at *M*. This action causes the shank of the reamer *N* to assume a central position in the holder, which position differs from the center line of the work by an amount indicated between the two arrows at *O*. From these examples, it can be readily understood that a very simple type of floating holder will take care of variations in the vertical position of the holder and work, but will not give good results when there are other inaccuracies in alignment.

Full-Floating Holders.—In Fig. 129 is shown at *A* a type of holder designed to overcome the ordinary difficulties found in floating reamer holders. The body *B* contains a floating member *C*, which is tapered to receive a taper-shank reamer. A ball thrust bearing is provided at *D*, and all the thrust is taken at this point. The driving action is by means of a pin *E*, which floats

freely in the shank as shown. It is restrained by the setscrew *F* so that it does not have too great a movement, and at the same time it is perfectly free to take a central position with respect to the work. In action, the tendency is for the reamer to parallel itself to the hole, the action being assisted by the wide thrust bearing mentioned.

Another type of floating reamer holder designed to correct misalignment is shown at *G*. The shank *H* is held in the turret and the reamer shank *K* is permitted to float in several directions.

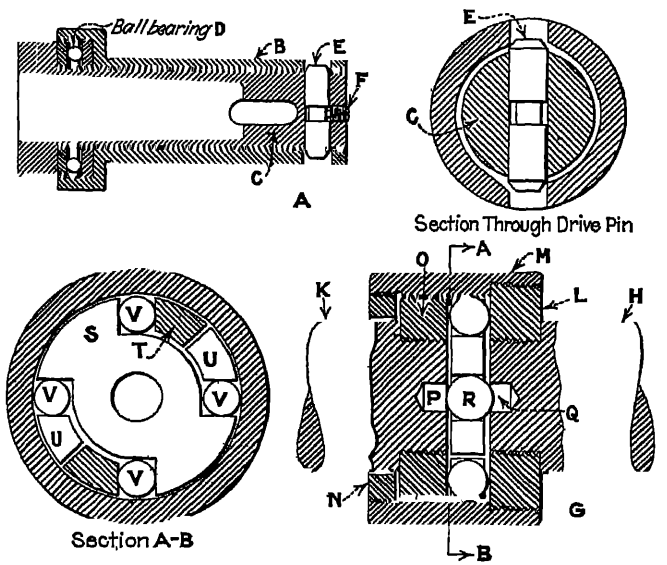


FIG. 129.—Two types of floating reamer holders

The shank *H* is threaded to receive the nut *L*, which is screwed up against the shoulder as shown. On the outside of this nut a retaining collar *M* is screwed. The front end of this collar is threaded internally to receive an adjusting nut *N*, which controls the amount of float permissible in the reamer. The shank of the reamer is fitted with a nut *O* that is intended to prevent the reamer from pulling out of the holder. Hardened pins are inserted at *P* and *Q*, and against these pins the thrust of the reamer is taken through the ball *R* which is interposed between them The driving is accomplished by means of a floating member *S*, which is cut out as shown in the end sectional view Each of the collars *L* and *O* has two lugs on it, as shown at *T*

and *U*. There are four balls *V* interposed between the driving members. When in operation the reamer enters the hole and parallels itself to it due to the floating action, which at the same time permits a driving movement that is not influenced by the location of the center of the holder. A floating action is thus obtained which takes care of errors in alignment, both vertical and horizontal.

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CHAPTER XI

CROSS-SLIDE TOOLS

TYPES AND PROPORTIONS OF TOOL HOLDERS AND BLOCKS—METHODS OF CLAMPING AND ADJUSTING TOOLS—CUTTING OFF AND FORMED TOOLS—CIRCULAR FORMING TOOLS—OVER-SHOT TOOLS—TURRET TOOLPOSTS

In connection with turning and boring operations with tools attached to the turret, work is also performed by cross-slide tools, oftentimes used simultaneously. Forming, facing, grooving and cutting-off operations are usually done by tools on the cross slide of the machine. There is obviously a great saving in production time when combinations of operations can be made; but in order to obtain maximum efficiency from the tooling, both turret and cross-slide tools must be designed so that there will be no interferences to prevent them from being used at the same time. Cases are occasionally found where the tools must be operated separately, but this method can nearly always be avoided by a careful study of the various cuts to be made and a consistent tool application.

The different movements of both turret and cross slide must be considered when designing tools. The positions of the tools and their relations, not only to each other but to the work, are of great importance. A turret layout showing all tools in position will be found a great help in avoiding interferences. When machining short work which requires short turret tools, there is not likely to be very much trouble, but when long boring bars or turning tools are used, there are chances for interference. It is not at all difficult to avoid trouble between tools that are working simultaneously; it is the idle tools that project from the turret at various angles that are apt to do the damage.

The diagram shown in Fig. 130 illustrates a common source of trouble caused by tool interferences. In this example the work *A* is quite long and projects some distance from the face of the chuck. It is to be bored and reamed with turret tools and faced with special cross-slide tools as indicated, the roughing tools being

at the front of the machine and the finishing tools at the rear. The work is held in special chuck jaws cut away so that the back-facing tools can operate without interference. The boring bars *B* and *G* are long in order to pilot them in a bushing in the chuck and thus give greater rigidity. The reamer bar *F* is arranged so that it will "float," but it is also piloted in the same manner as the boring bars. The front cross-slide tool block *E* has two tools *C* and *D*, used for rough-facing both sides of the flange. The rear tool block *H* contains two finishing tools as indicated.

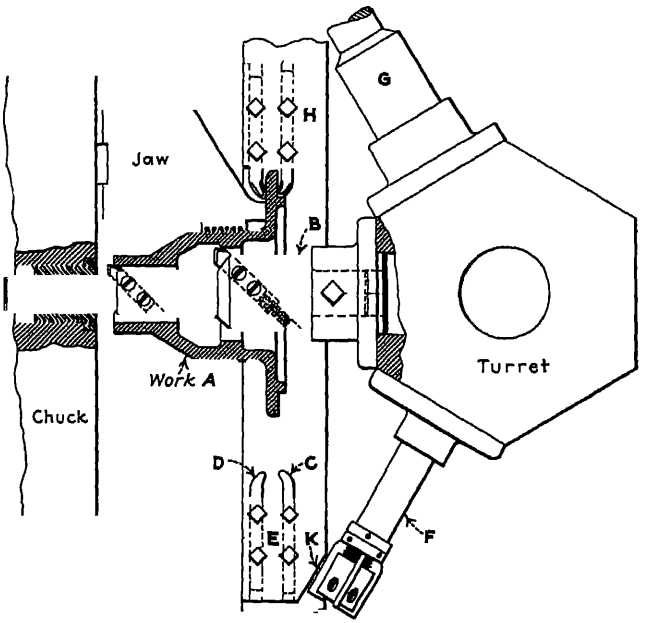


FIG 130.—Interference of turret tools with cross-slide toolblock.

The tool designer can easily design these various tools so that each is apparently all right for the purpose, yet when in use on the machine there would be an interference with the front cross-slide tool block by the reamer bar *F* at the time when the rear cross-slide tools are finishing the flange. This action is shown in the diagram. There is a very simple way out of the difficulty, either by placing the tools in every alternate turret hole, or by cutting away the toolblock a trifle as shown at *K*. If it were necessary to use several other turret tools in the same set-up, the

condition would be more serious, but some way out of the trouble could be found by careful study.

Another situation which is sometimes troublesome on certain types of turret lathes, is the interference of long boring bars with the "spider" or spoke wheel used for the longitudinal movement of the turret slide. To avoid this trouble, an extra long pinion shaft and a special bracket to carry it may be required. Some turret lathes have the turret set at an angle, so that as it is indexed the tools swing clear of the spider. Other machines avoid the possibility of trouble of this sort by doing away with the spider entirely and using a handwheel in place of it. The diameter of the wheel is small enough to obviate the possibility of interferences.

The greatest care should be taken by the designer to look into the various points mentioned and see that there is no possibility of one tool striking another or hitting any part of the machine, either during the machining operations or while indexing the turret. The layout of tools showing all turret and cross-slide tools in their operating positions is of great value in preventing any interferences. The matter of turret layouts will be fully discussed in a subsequent chapter.

The following points of design are of importance and should be considered:

(1) The quantity of pieces to be manufactured is a factor of great importance, as it controls the cost of the tool equipment. Naturally, a small number of parts indicates inexpensive tooling, and tools of standard form should be adopted for this kind of work wherever possible. In high production the special tooling expense need not be considered very carefully, the great factor being a reduction of time in the process of machining. Hence, special tools designed for high production should be so arranged that they can be readily replaced when worn, easily set and conveniently adjusted.

(2) The material to be machined must be considered when designing cross-slide tools, in order to obtain the easiest cutting action and the removal of the stock in the best manner. For example, cast iron and other materials of short grain can be machined with blunt tools, or those which do not have any "lip." Copper, steel and some aluminum alloys require tools of such a nature that they produce a shearing action on the materials. Occasionally this point affects the design of the tool holder,

making it desirable to set it at an angle rather than straight. It is therefore advisable to consider the material to be cut before starting the design.

(3) The cutting action of cross-slide tools makes it necessary to hold them with exceptional rigidity in the tool supports. In forming cuts it is very important, and also in cutting-off operations. When facing cuts are to be taken, the action is not as severe as when cutting directly down into the body of the metal; nevertheless tools must be held with sufficient firmness, so that

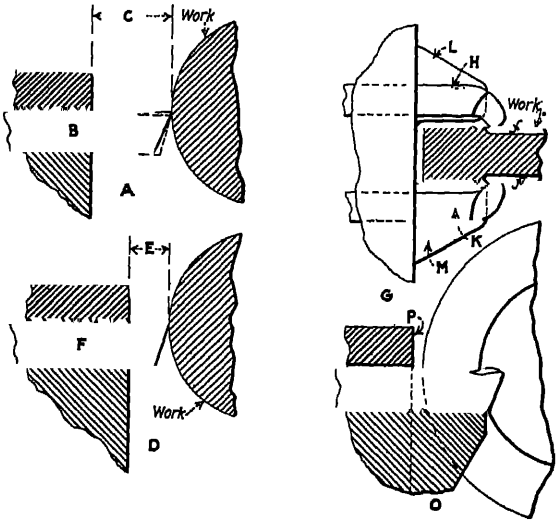


FIG 131.—Importance of tool support

no "chatter" will develop. It is advisable to use tool sections as large as possible, in order that the heat generated by the cut will be carried away rapidly.

(4) The method of adjustment of the tools should receive thought. The "sledge-hammer" method of adjustment is crude and out-of-date. Accurate work requires that proper provision be made for easy and accurate setting of tools. When multiple toolblocks are used, as when several shoulders are to be held closely to size, it may be necessary to grind the sides of the tools and fit them accurately to slots in the blocks. Holding-down screws and adjusting screws should both be arranged with regard to the convenience of the operator. They may be operated by a

wrench, if desired. Some operators prefer a screwdriver for adjusting screws, while others like a wrench. The designer may be governed by the practice in the shop which is to use the tools.

In order to obtain maximum efficiency from cutting tools, they must be so supported and held that there will be no chance for chatter. The diagrams shown in Fig. 131 illustrate some important points in connection with tool support. In the example *A* the tool *B* extends beyond its support a distance represented by the letter *C*. If the work which is to be done does not require a heavy cut, this amount of overhang might not cause any difficulty. On the other hand, if the cutting action is severe the tool might be depressed, as shown by the dotted lines, thus causing chatter and injury to both tool and work.

In the example shown at *D*, the tool *F* overhangs beyond the block only the distance *E*. This arrangement would be much better for heavy cutting than the example *A*. The nature of the work and the kind of cut required make a considerable difference in the amount of overhang permissible. A parting tool must necessarily overhang sufficiently so that it will cut off the work without interference by the tool block against the side of the work. For this reason, a parting tool should be made deep in order that the tool itself will have sufficient rigidity to withstand the pressure of the cut.

In the example shown at *G* the two tools *H* and *K* are used for facing the sides of the work, as indicated. As the tools project beyond the holder some distance, it is advisable to support them in some way so that they will not deflect while cutting. The tool block is therefore built out in the form of a shelf, as shown at *L* and *M*, thus giving the necessary support. A side view of the toolblock illustrating this point clearly is shown at *O*. An additional refinement for a case of this kind would be a projection of the cap block *P* of such shape that it would extend out over the tool, and permit the use of a holding-down screw as far out on the tool as possible. These points in tool support are all of importance and should be carefully considered when designing cross-slide tool blocks.

Cross-Slide Tool Blocks.—There are a number of styles of tool blocks in common use on both turret and engine-lathe cross slides. Several of these types are illustrated in Fig. 132 The example *A* shows a form of toolpost in common use on both engine and turret lathes This form is familiar to all shop men and

designers. The post B is circular in form and fits the T-slot in the cross slide at C. The tool F rests on a rocker D supported on the curved surface of the collar E. The tool is held in place after adjustment by means of a collar-head setscrew L.

One advantage of this type of holder is that it permits the tool to be set either above or below center, as indicated by the dotted line. For this reason it is commonly used on an engine lathe, as tools vary in depth considerably and a vertical adjustment of

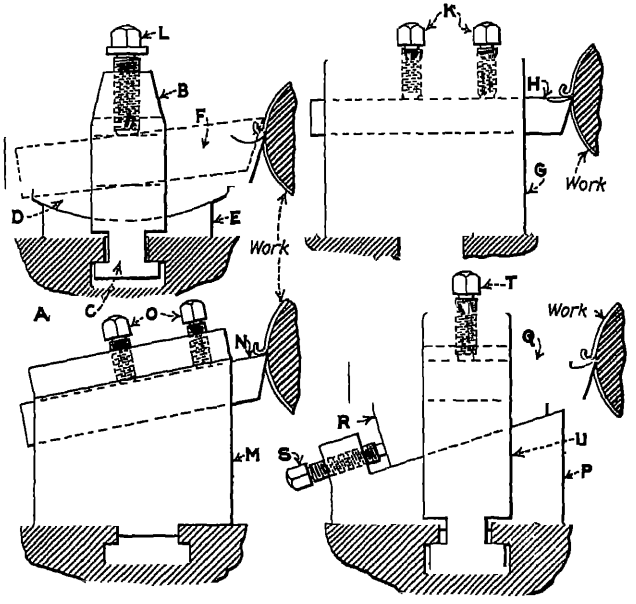


FIG. 132.—Cross-slide toolposts and blocks

some sort is essential. For single cuts on turret lathes this type of holder can often be used to advantage, and for very heavy cutting two toolposts can be used in combination with a long tool, thus obtaining exceptional rigidity. For operations requiring two or more tools and in cutting shoulder distances close to size, toolposts of this kind are not generally used in high-production work, as it is much more difficult to preserve the setting.

Another type of tool block in which the tool is set permanently at an angle is shown at N. This type is useful when cutting steel or other materials which require the tool to be set at an angle or "lipped" to make the cutting action easier. The block is usu-

ally of cast iron, while the cap is of steel. Two setscrews *O* are used to hold the tool in place. This is a very simple type of block, and no setscrew is provided for adjusting the tool.

Another example, shown at *G*, is a simple cast-iron block fitted to the T-slot on the cross slide and held down by means of bolts in the usual manner. The tool *H* in this case is set straight on the center of the work. It is held in place by two setscrews at *K*. The cap in which the setscrews are located is usually made of a steel block. This block should be of sufficient thickness to give a good thread for the setscrews and at the same time

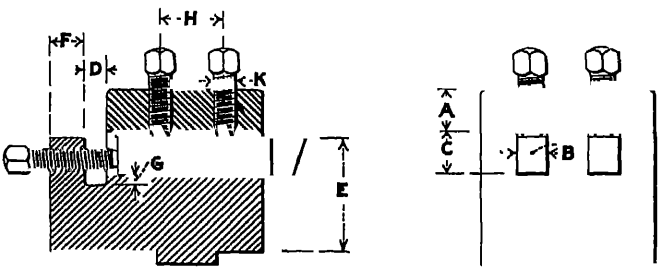


FIG. 133.—Toolblock proportions.
(A) Front toolblock with tools up to $\frac{1}{2}$ in wide· A = 1 in Tools up to 1 in wide· A = $1\frac{1}{4}$. Rear toolblock with tools up to $\frac{1}{2}$ in wide A = $1\frac{1}{8}$ Tools up to 1 in. wide: A = $1\frac{1}{4}$. (B) Tools up to $\frac{1}{2}$ in wide B = $\frac{1}{64}$ in plus width of tool Tools $\frac{1}{2}$ in and over: B = $\frac{1}{32}$ in plus width of tool (C) Tools up to $\frac{1}{2}$ in height of tools: C = $\frac{1}{32}$ plus height of tool Tools $\frac{1}{2}$ in height and over· C = $\frac{1}{16}$ in plus height of tool (D) $\frac{3}{8}$ to $\frac{5}{8}$ in on all toolblocks when designed with block-adjusting screw, as shown (E) This dimension is always to be shown on assembly drawing, and is the dimension to center line of spindle. (*F*) Tools up to $\frac{1}{2}$ in wide. F = 1 in Tools over $\frac{1}{2}$ in wide F = $1\frac{1}{8}$ (G) $\frac{1}{8}$ to $\frac{1}{4}$ in clearance (H) Four times the diameter of *K*. (K) The diameter of screw.

resist the pressure of the screw. When a number of tools are used in the same block, care should be taken to make the cap of sufficient depth to withstand the thrust of the numerous setscrews used to hold the tools in place.

An example of an adjustable tool block is shown at *P*. This block passes through a slot in the post *U*. The latter is fitted to the T-slot in the cross slide. The tool *Q* rests on a wedge-shaped piece *R*, which may be adjusted by means of a setscrew *S*. The tool is held in place and the entire unit clamped by means of the screw *T*. This toolpost allows the tool to be raised or lowered without difficulty according to the adjustment of the taper block *R*. There is no provision for tipping the tool, as in the example *A*. All of the blocks shown in this illustration are of use for various kinds of work, and they can be adapted to a variety of conditions In Fig. 133 is shown a diagram of a

simple form of tool block with the proportions of the various parts. This data will be found useful in proportioning tool blocks for ordinary work, and the standard sizes given can be used as a guide when designing. No particular instructions are required for using this information, as the chart is self-explanatory.

The importance of an efficient method of holding a tool in position and adjusting it, has already been mentioned. Several examples which illustrate methods useful for this purpose are shown in Fig. 134. The illustrations at *A* and *B* show, respectively, a side and top view of a simple form of tool block *C*. The

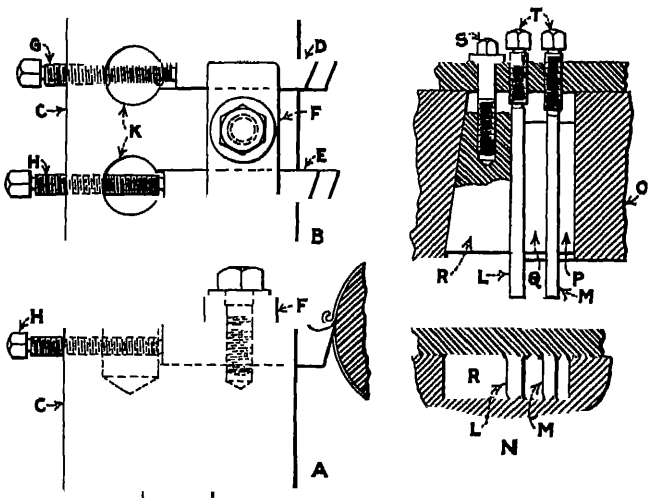


FIG 134.—Methods of clamping tools.

tools *D* and *E* are set in slots in the block, and the method of clamping is by means of a single strap *F* having a screw through it midway between the two tools. Adjustment is provided in the setscrews *G* and *H*. Clearance holes are drilled at *K* in order to make it easy to plane out the tool slots.

For light cutting and when only two tools are to be held, this type of block will be found convenient and economical, as it can be made up cheaply and does not require an upper cap or plate. If the cutting action is severe, the same type of block can be used, except that it should be made deeper and the tools longer, so that two straps instead of one can be used for holding and clamping tools. It is advisable to place the forward clamp as close to the front end of the block as possible, when two clamps are used

In designing tool blocks for grooving tools, a confined situation may require extraordinary methods of holding and clamping. An example which illustrates this point is shown at *N*. The two tools *L* and *M* are used for grooving, and are set in the block *O* with spacers *P* and *Q* of proper size to locate the tools in their correct positions. The adjusting screws at *T* can be set up to regulate the depth of the cut. The peculiar part of this tool holder is in the method of clamping, which is done by means of a

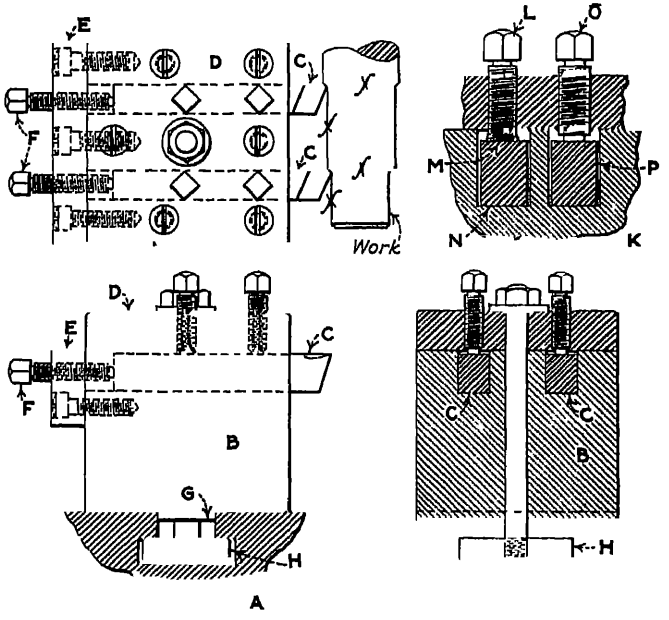


FIG. 135.—Toolblocks with provisions for adjustment.

wedge *R*. This wedge is operated by means of a special screw *S*, the action of the wedge causing the tools to be firmly gripped between the wedge, the filler blocks *P* and *Q* and the edge of the slot in the tool block. In adjusting the tools, the wedge may be slightly loosened, if necessary, and adjustment made before tightening. In many cases it is unnecessary to disturb the screw *S*, as sufficient pressure can be brought to bear on the adjusting screws *T* to make the correct setting.

In Fig 135 is shown a type of tool block at *A* designed particularly for turning two diameters. The tools *C* are held in slots in a cast-iron block *B* by means of square-head setscrews A steel

plate *D* acts as a cap on the top of the block; and the diameter adjustments are made by means of setscrews *F*, which are held in a strap *E* at the back of the block. This holder represents a simple form which has the advantage of being made up cheaply, as it is a built-up type which does not necessarily require any pattern, yet it is thoroughly substantial and will give good results. There are numerous cases where a design of this sort will be found convenient, not only for turning operations but for grooving or forming. It is only necessary to proportion it to the work for which it is to be used, and provide the slots for the necessary tools, together with the methods of holding and adjusting.

Locating and holding the block down on the cross slide are accomplished by means of the tongue *G* which enters the T-slot. The shoe *H* is used to draw the block down firmly by means of a bolt which extends entirely through the block. The shoe is a simple strap of proper size to fit the T-slot; it is usually standardized, and often made up in quantity.

The type of setscrew used to hold down a tool is quite important, and the material from which it is composed should also be given consideration. In the section at *K* the tool *N* is held in place by means of a plain square-head setscrew at *L*. The end of this screw *M* is likely to become enlarged by use or abuse until it is very difficult to operate it if made in the manner shown. The tool *P* is held by a square-head setscrew *O*, and the end which bears against the tool is relieved, so that under no circumstances can it be distorted so as to cause trouble.

Setscrews should always be hardened, and for severe service the material from which they are composed should be considered. The authors have found Hy-ten steel exceptionally well suited for setscrews subject to hard usage. Tool steel is also used, but considerable care should be taken to draw the temper sufficiently, so that it will not be brittle.

An important point in designing tool blocks in connection with the setscrews used to hold the tools in place, is the amount of thread which the setscrews should have in the cap or block. In general, the diameter multiplied by 2 will be found sufficient, but a little more than this is an advantage in the majority of cases. Some of the points mentioned here may be thought by the tool designer to be more or less unimportant. It must be remembered, however, that care taken in the design will result in much less trouble in the factory, and the tools will stand up and produce

the work much better than if some of these small details are overlooked or neglected.

Multiple Tool Blocks.—In the design of multiple tool blocks for the cross slide of either a turret or engine lathe, the work which is to be done naturally affects the design strongly. Occasionally, cross-slide tools are used for turning various diameters, and at

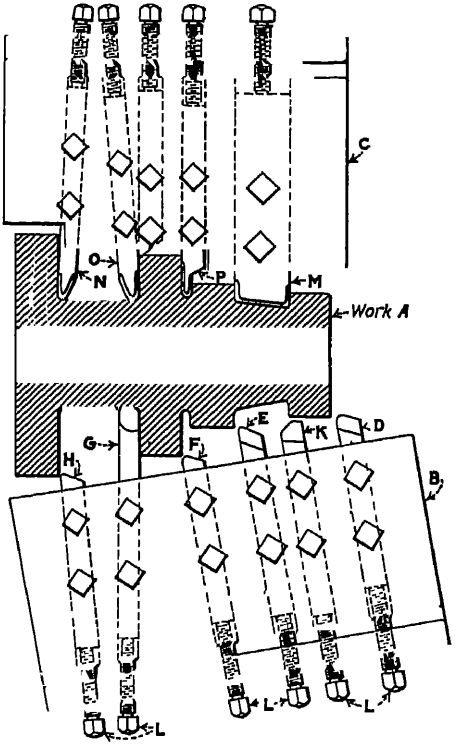


FIG 136.—Multiple toolblock for cluster gear

other times only for facing, grooving or cutting off. There are cases when the front tool block is used for turning, while the rear tool block may be utilized for forming or grooving. In general, when roughing and finishing cuts are made by the front and rear tool blocks working one after the other, the front block is used for roughing while the rear is used for finishing. There is a reason for this, as the cutting action on the front block is downward against the body of the cross slide. Therefore, it is more suited to heavy cutting. The rear block, on the other hand, is subjected

to a lifting action which makes it advisable to use it for lighter cutting.

An example which illustrates one use of multiple tool blocks on the front and rear of the cross slide is shown in Fig. 136. The front block *B* carries the tools *D*, *E*, *F*, *G* and *H*. All these tools are used for turning the various diameters, according to their positions. The tool *K* is a chamfering tool, and simply breaks the corner of one of the gears after the turning operations have been finished. All of the turning tools are arranged so that they are operating simultaneously, thus saving a great amount of time in production. The tool block *B* in which they are held is of a simple type, containing slots properly spaced to hold the tools. All adjustments are made by means of the setscrews shown at *L*. The block is set at an angle in order to avoid too much overhang for the tools cutting on the small end of the work.

The rear tool block *C* contains tools *M*, *N*, *O* and *P*, all of which are used for sizing the shoulders, facing or grooving. None of the tools in the rear block are used for turning, but an important point is the fact that the spacing is such that shoulder distances are accurately cut and sized. The construction of the rear block is similar to that used at the front. Setscrews are provided for adjustment, as shown.

These tool blocks are both designed for use on a heavy-duty engine lathe, but it will be possible to use something of the same sort on a turret lathe when the cross slide is provided with a longitudinal feed. It would doubtless be necessary to provide accurate longitudinal stops if used on a turret lathe, in order to make sure that the shoulder distances are held accurately to size.

Example of Multiple Cutting.—Considerable time can often be saved by machining several cylindrical pieces in the same setting by grouping them together on an arbor and providing a gang of tools of suitable size and arrangement. Fig. 137 shows an example of this sort in which three pieces of work *A* are held on an arbor *B* with a special driver *C* in a slot in the faceplate. The other end of the arbor is supported on the center, as indicated. The work is placed on the arbor and driven by means of a key in a keyway in the work. Spacing collars are interposed between the various pieces in order to allow room enough for the various tools to operate.

The front tool block *D* contains a group of turning tools, the operation of which is somewhat out of the ordinary. The two

principal diameters of each piece are turned by a longitudinal feeding movement of the cross slide in one direction. The small shoulder is turned by other tools by feeding the cross slide in the reverse direction. The rear tool block *E* contains a group of tools used only for grooving and facing. As these tools are set accurately, the various shoulder distances and faces are accurately

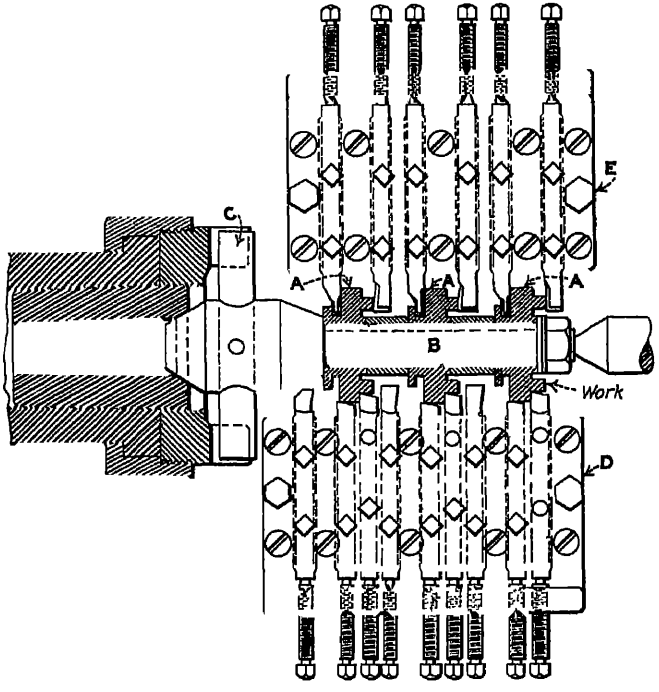


FIG. 137.—Front and rear toolblocks with multiple gang tools

preserved. In both blocks accurate adjustment is provided by means of backing-up screws.

In many cases where work of this kind is to be done it would be necessary to provide the block with accurately sized slots, and the tools would need to be ground on the sides to fit these slots. This can sometimes be avoided by using a special tool-setting gage, which can be arranged as a part of the block or can be a separate unit. The design of a gage of this sort will depend entirely upon the nature of the work. The ingenuity of the designer will be called into play to look into such points as this and provide means for accurate setting.

Very frequently the matter of tool setting is not considered carefully; and as a result when the blocks are placed in the shop the operator is compelled to waste a great deal of time in setting up the tools, and "cutting and trying" until they produce the work according to requirements. The careful designer considers the operator when designing and provides all necessary adjustments, together with means of setting up the tools so that they do not cause trouble when placed in the shop.

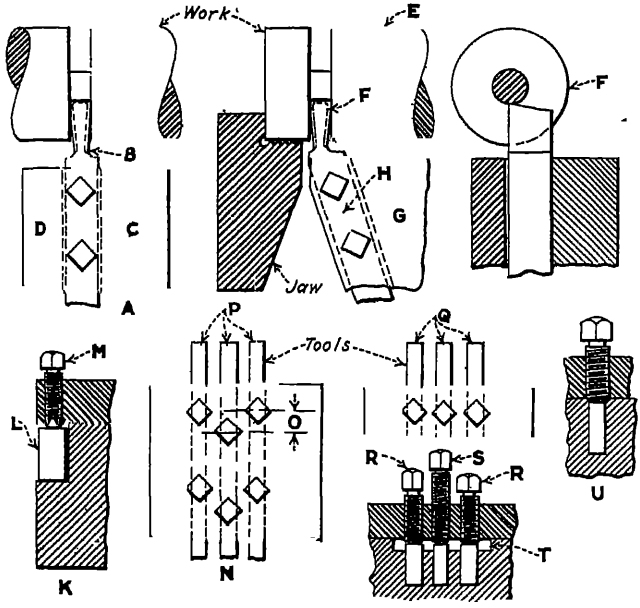


FIG 138.—Details of toolblocks for parting tools

In the design of parting or cutting-off tools it is particularly important to make the holder in such a way that there will be no opportunity for movement of the tool during the operation. Parting tools are usually relieved on the sides, as otherwise they are likely to rub and tear the side of the groove and leave a ragged surface. A grooving or parting cut is one of the most difficult, particularly when the groove is deep and narrow, as shown in the detail *A*, Fig. 138. The type of tool often used for this purpose is shown at *B*. It is held in a slot in a holder *C* by means of two square-head setscrews. A tool of this kind should be made as deep as consistent with the nature of the work which

is being cut, as the pressure upon it is excessive, and it is likely to break when the cut is very deep.

When grooving tools are made, if the groove is to be held closely to width and is rather deep, it is generally necessary to use roughing and finishing tools, the finishing tool not being back tapered, but having a slight amount of clearance on the sides. As the finishing tool has very little work to do, the width of the slot can be easily preserved. For very wide and somewhat deep grooves, it is advisable to do the sizing for width with two tools, so made that they can be adjusted to compensate for any errors in grinding on the sides.

In the tool holder shown at *C*, the slot for the tool is cut in the body and there is a projecting portion at *D* which prevents working close to a shoulder or to chuck jaws. In many cases this would not be a good holder to use, for the reason stated. There are two ways of avoiding any such condition; one of them being shown at *H*. The work *E* is held in chuck jaws, so that there is not much space for any projection like that at *D*, beyond the tool. Hence, a bent tool like that at *F* can be held in a holder *G*. The slot which contains the tool is open on the side, thus allowing the cutter to work close up to the chuck jaw without interference.

Another way is to make the tool holder straight, but open on one side; and this method is probably better than that shown, as there is less trouble in setting the tool and less work in making the holder. The illustration at *K* shows the tool *L* held in an open-side holder by means of the setscrew at *M*. This method is used where tools must be set to operate close to a shoulder.

When several narrow tools are used close together for grooving, as shown at *N*, it may be found difficult to locate the holding-down screws so that they will be easily accessible. The three tools *P* illustrate this point very well, and the method of staggering the setscrews is clearly shown. By making the distance *O* sufficient, so that the operator can place a wrench on the various setscrew heads, no difficulty will be experienced. This method is objectionable because the screws are sometimes placed too far back from the end of the tool, and therefore do not hold it as firmly as is needed. In the example *Q* the three tools are held by three setscrews placed in line with each other, but the screw *S* is higher than those marked *R*. The operator can therefore easily use a wrench on any one of them without interference

The caution is here given to avoid the use of holding-down screws of too small a diameter. Many designers make errors of this sort due to a lack of thought. In holding narrow tools like that shown at *U*, it would appear that the largest setscrew which could be used would be one which is no larger than the width of the slot. Yet, if the tool block is relieved, as shown at *T*, and the tools project slightly above the relieved surface, the setscrews can be larger than the width of the slot and thus have greater holding power. An advantage in using the setscrews is that they are less likely to be broken or mutilated when in use. This is

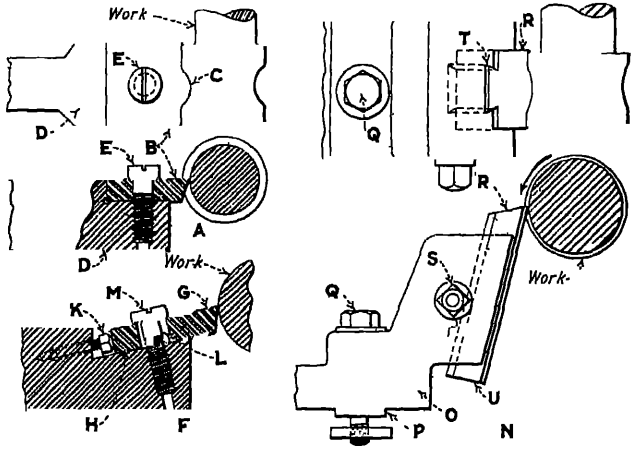


FIG. 139.—Flat-blade and dovetail forming tools.

particularly noticeable when small headless setscrews are used. It is advisable to avoid this type of screw for any holding-down operations, as the slots are likely to become broken so that they are useless.

In making a formed cut, a tool can be made having a contour of the correct shape so that it will reproduce this shape on the work. When the form is simple and does not require to be held very accurately, a flat-blade cutter can be utilized and very good results obtained. If it is necessary to make the form to an accurate size other methods are to be preferred. Fig. 139 shows at *A* a flat-blade forming cutter *B* designed for the purpose of cutting the form *C*. The cutter blade is ground to the required shape, and it is held in a shank *D* by means of a screw *E*. It is backed up against the shoulder on the holder, as indicated.

This holder may be used in a standard toolpost or in a tool block, the shank being proportioned to suit the conditions. For simple work and production which is not very high, this device will give fairly good results.

Another example of a somewhat similar tool is shown at *F*. The blade *G* is set at an angle and is held against an angular surface *H* and backed up by a setscrew *K*. The slot *L* allows the

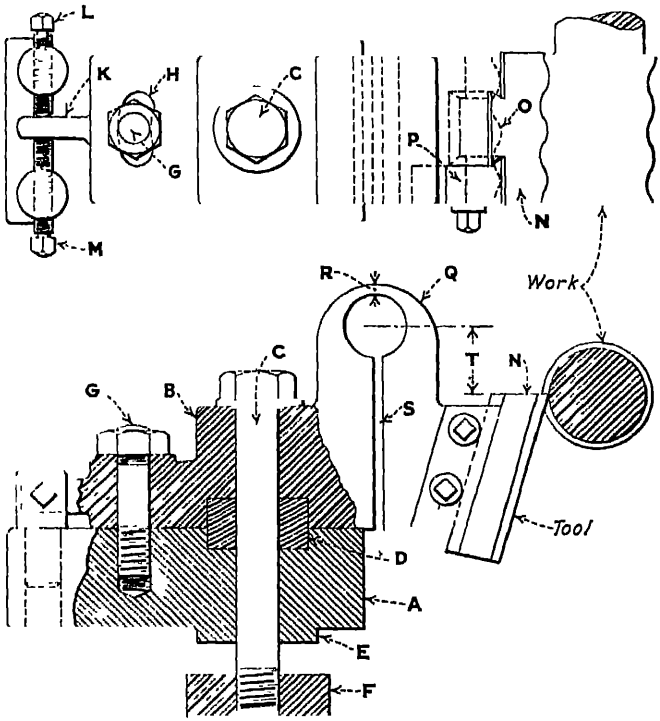


FIG. 140.—Goose-neck holder for forming tools.

tool to be adjusted slightly, and after this adjustment has been made the special screw *M* is tightened, thus holding it firmly. For steel work when a little shear is required to produce a smooth cutting action, a holder of this general type can be used. It is advisable, however, in the majority of cases to do away with the adjustable feature and bring the back of the plate solidly against the holder. All necessary adjustments can then be made by an adjustment of the cross slide or the holder in the tool block.

Another type of tool frequently used for forming is the dovetail forming tool shown at *N*. The toolblock *O* is designed to fit the cross slide of the machine, and is located on it by means of the tongue at *P*. It is held in place on the slide by one or more bolts *Q*. The tool *R* is somewhat different from others which have been described. It is a long piece of tool steel, dovetailed at *T* to fit the holder. It is clamped in the dovetail by means of one or more bolts *S*, these being arranged so that they bear directly against the dovetailed surface.

Several methods of holding are in vogue, but hook bolts cut out to fit the dovetail will usually give very good results. Sometimes the "pinch-binder" principle is used, the holder being split in the middle and drawn up tightly on the dovetail by means of a couple of bolts. Forming tools of this kind often require support at the point *U* when the cut is very heavy, as otherwise they are likely to slip and change their position with respect to the center of the work. The holder can be designed so that a backing-up screw may be placed at this point if desired.

In order to avoid chatter under heavy forming cuts, the "gooseneck" principle can be applied to the tool holder. On some kinds of forming cuts it is very difficult to obtain a smooth surface free from chatter marks, but this trouble can be avoided by the use of a holder like that shown in Fig. 140. The block *A* fits the cross slide T-slot at *E*. Mounted on this block is a swivel member *B* which pivots on the hardened locating ring *D*. The block is held down by the bolt *C*, which draws up on the shoe *F* in the T-slot of the cross slide, thus holding the entire unit down firmly. The provision for side adjustment is made in the slot *H*, the binder stud *G* being provided with a nut to make the unit secure after it has been adjusted.

The member *B* has a "tail" *K*, which is held between two setscrews *L* and *M*. These two screws can be used to control the position of the swiveling member. The other end of the holder is drilled at *Q* and slotted at *S*, and the portion *R* is left rather thin so as to permit it to spring easily. The tool *N* is fitted to a dovetail at *O*, and is clamped in place by means of a shoe *P*, which fits one side of the dovetail. The distance from the top of the cutter blade to the center of the hole, as indicated at *T*, should be sufficient to allow the movement or deflection of the tool to carry it well away from the work, so that it will not dig in or chatter.

Attention should be paid to the thickness of the wall at R, as upon this depends the amount of spring in the tool. It should be thick enough to stand the stresses imposed by the cut, and thin enough so that it will spring readily. The member B should be made of tool steel hardened and spring tempered at R. It is usually necessary to place a flat spring in the slot S in order to prevent too much vibration under the cut. This spring can be

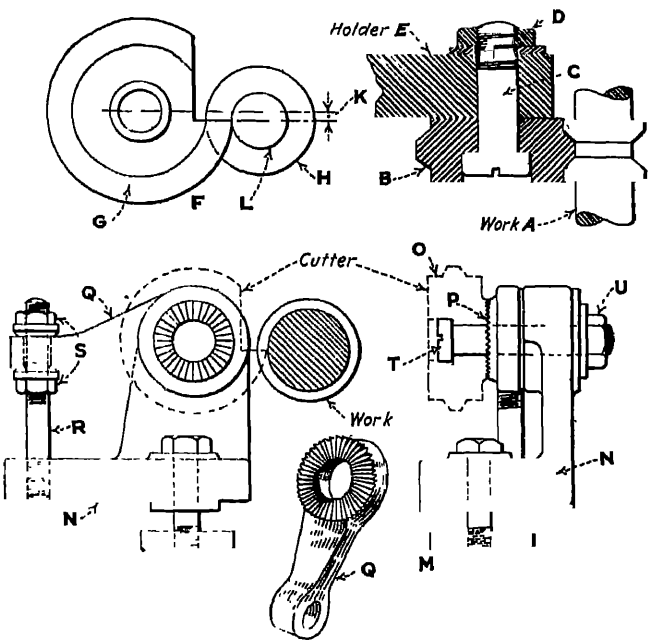


FIG. 141.—Circular forming tools

adjusted up or down in the slot as may be desired. Tools of this general type are useful not only for forming cuts, but for threading or work of like character. In fact, for any severe cutting which is likely to produce chatter, a tool of this kind is an effective remedy.

Circular Forming Tools.—Another type of tool very useful for forming cuts is the circular forming tool. Two examples of this sort of tool are shown in Fig. 141. The work A is to be formed by a cutter B held in place in the holder E by a special screw C. This cutter can be adjusted by loosening the nut D

and turning the cutter around to the position required. In order to illustrate the cutting action of the forming tool, a diagram is shown at *F*. Here the tool *G* represents the circular forming tool and *H* shows the work.

The position of the cutting edge of the formed tool is below the center of the tool but on the center of the work. In other words, the forming tool is sharpened considerably below its own center. The designer will note that the terms above and below depend upon whether the tool is applied to the front or rear of the cross slide. In the former case the cutting edge would be below center, while in the latter it would be above center, because the tool would be inverted. In either case, however, the cutting edge would be on the center of the work. This vertical distance between the centers is indicated at *K*. The purpose of cutting the tool below its own center is to provide greater clearance at *L*, so that there will be less likelihood of the tool rubbing and losing its edge due to an insufficient amount of clearance.

An improved form of tool holder for circular forming tools is shown at *M*. The holder *N* is attached to the cross slide in the usual manner by means of a bolt and shoe. The cutter *O* shown by the dotted line, is drawn back against a serrated member *P*, and held in place by means of the screw *T* drawn up solidly by the nut *U*. In order to provide a means of accurate setting after grinding, the arm *Q* is mounted in such a way that the two nuts at *S* can be adjusted up and down on the stud *R*, which is placed in the body of the fixture. As the side of the forming tool is serrated to correspond with the teeth on the arm, the adjustment of the tool can be very easily made. The arm is shown in detail at *Q* in order to make the matter somewhat clearer. This type of circular forming tool has met with great favor, and it is in common use throughout the country.

Due to the fact that a forming tool has its cutting edge below its own center, it is evident that the radial length of the shoulder or steps on the tool must be less than the actual shoulder to be formed on the work. For tools which have no rake, simple formulas will enable the designer to figure the required diameters without difficulty. When the cutting edge, however, must be made with more or less rake, other formulas must be used. In order to avoid complications on the matter, we shall concern ourselves only with the simple type of circular forming tool, a diagram to illustrate which is shown in Fig. 142. Referring to

the diagram, the various formulas given here will be readily understood.

In order to find the diameter of circular forming tools it is first necessary to find the value of W in the right triangle DEC, or

$$W = \sqrt{R^2 - H^2}$$

In this equation,

R = Radius of largest diameter cutter.

H = The distance above or below center of work that the center of tool is set.

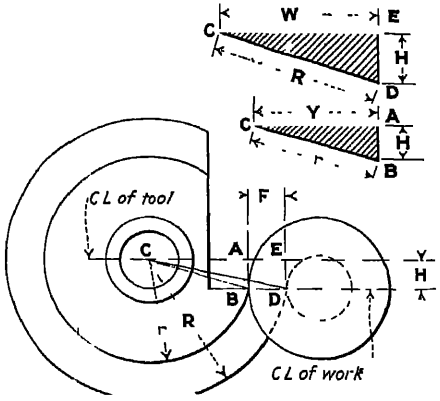


FIG. 142.—Layout for circular forming tool.

In order to find the value of r in the right triangle ABC,

$$r = \sqrt{Y^2 - H^2}$$

In this equation,

$2r$ = Small diameter of cutter.

$Y = W - F$.

F = Half the difference between the circular diameters of the work.

In connection with forming cuts of various kinds, it is necessary to mention a type of tool which is not in very common use, yet which has a number of advantages. Referring to Fig. 143, two pieces of work are shown at A and B; in one of these a deep groove is cut at C while in the other case a form cut is made at D. Either of these two jobs can be done with a circular or dovetail forming tool. The cutting action, however, in either case is rather severe, especially if the work is of large size.

A type of tool which will give good results for work in this character is shown at E and is designated as an overshot tool. The tool block is fitted to the cross slide of the machine and is held firmly in place by means of the bolts L which draw up on the shoes K. The tool G is set so that it overhangs the work and so that it is more or less tangent to it when the full depth of the cut has been reached. The tool is held by means of four setscrews

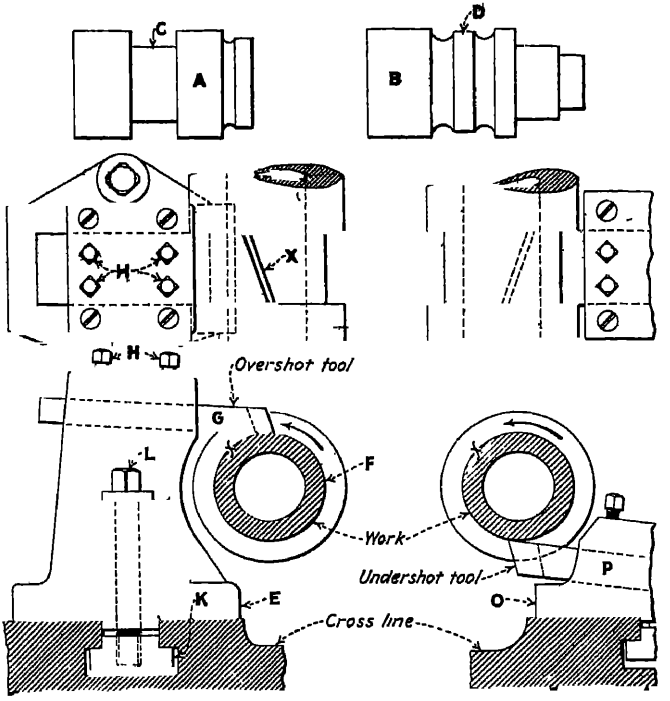


FIG 143 —Overshot and undershot tools

at H, and it is set at a slight angle in order to provide clearance. The front of the tool is also cut at an angle, as shown at X.

It is evident that when the cross-slide feed is started, the tool will be fed inward toward the center of the work and that there will be a shearing action caused by the angular surface X, so that the chips will roll up and part from the metal with a minimum amount of friction. An advantage of this type of tool is that the diameter of the work can be held very accurately. A principle similar to this is used in universal turning tools for steel,

and it may be here stated that this type of tool is more adapted to steel than it is to cast iron. The tool can be formed to any shape desired, and as it needs to be ground only against the angular surface *X*, it will hold its shape without difficulty.

Another type of tool employing a similar principle is shown at *P*. It is called an undershot tool and is placed at the rear of the cross slide in a holder similar to that shown at *O*. This type is not as common as the other, and it is ordinarily not considered as good. If the cross-slide gibbing is slightly loose, there is

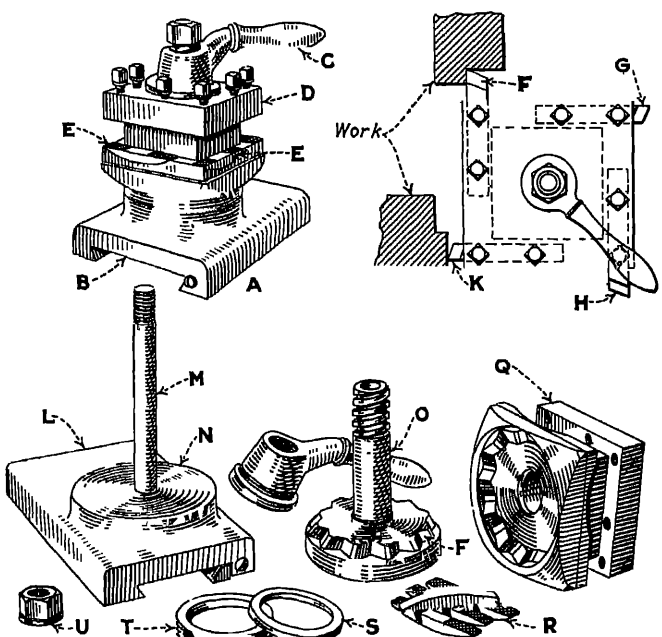


FIG. 144.—Turret toolpost for cross slide.

a lifting action on the tool which tends to produce chatter. For certain kinds of work, however, it may be found useful.

Turret Toolposts.—Work which requires several shoulders to be turned or sized may oftentimes be handled to advantage by means of a turret toolpost such as that shown in Fig. 144. The assembly shown at *A* gives a very good general idea of the device It is intended to be fitted by means of a dovetail *B* to the cross slide of the lathe. The body of the tool *D* is arranged so that it can be indexed into a number of positions and clamped

in place by means of the binder handle *C*. The tools are held on the hardened rockers *E*, and firmly secured by means of the set-screws at the top of the turret. The rockers permit a certain amount of adjustment to the tools, so that slight inaccuracies in grinding can be compensated. The tools *F*, *G*, *H* and *K* are

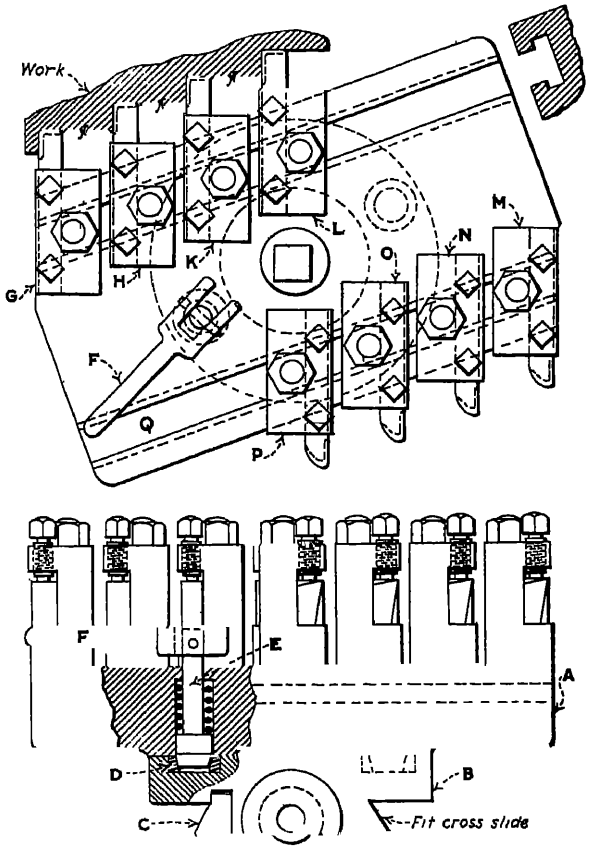


FIG. 145—Shoulder tool set-up on turret toolpost.

shown in the turret toolpost, and their application to the work can be readily seen by reference to the illustration. Two diameters are turned, roughed and finished without changing the radial position of the cross slide after the tools have been set.

The base of the toolpost *L* has a circular pad on it at *N*, in the center of which the stud *M* is fixed. On this stud the quill *O* is located, and at the lower end of the quill indexing teeth are cut

as shown at *P*. The turret body *Q* is mounted on the quill, and indexing is accomplished by loosening the binder handle and moving the turret around to engage with the various teeth shown. Other details are clearly shown at *R*, *S*, *T* and *U*. Turrets of this sort are very useful in manufacturing for either high or low production.

Another type of cross-slide turret toolpost is shown in Fig. 145. This example illustrates the possibilities of multiple cutting tools for shoulder work in connection with a turret-indexing device on the cross slide. The indexing portion *A* is mounted on a base *B* which is fitted to the cross slide and gibbed by means of the dovetail gib *C*. The indexing of the portion *A* is taken care of by means of a plunger *E*, which engages with various bushings *D* in the base *B*. The handle *F* makes the operation rapid, and it is so arranged that it will pull up the plunger and hold it out of engagement while the turret is being indexed.

The tool blocks *G*, *H*, *K* and *L* each contain a tool which is set to produce a given diameter on the work as shown. These tool blocks are tongued so that they fit the T-slot *R*, in which they can be adjusted longitudinally. The tools mentioned are used for the finishing operation on the work. The roughing is done by those shown at *M*, *N*, *O* and *P*. These blocks are arranged so that they fit a T-slot *Q*, exactly the same as that on the other side of the turret. The advantages of this style of turret tool block are evident, but when designing anything of this sort it must be remembered that a great deal of work is being done by the tools. As a consequence, the greatest care must be taken to make sure that sufficient strength is given to the various parts, to withstand the heavy cutting action.

CHAPTER XII

ATTACHMENTS FOR TURRET LATHES

FACTORS INFLUENCING THE DESIGN—DUPLEX ATTACHMENTS FOR TURRET—FORMING AND GENERATING TOOLS FOR TAPER TURNING AND BORING—ENGINE LATHE AND TURRET LATHE TOOLING—CROSS-SLIDE AND TURRET TAPER TOOLS—PLAIN AND ADJUSTABLE ATTACHMENTS—SPHERICAL AND CURVED SURFACES—INTERNAL AND EXTERNAL FINISHING—GENERATING AND FORMING ATTACHMENTS

Tapered and curved surfaces, both external and internal, often require special attachments in order to machine them accurately. Inside forms when of small diameter are often machined by the use of tapered or formed reamers; large diameters by a flat tool of correct shape, or by means of a generating attachment so arranged as to cause a single-point tool to travel along the taper or the form of the contour. Outside contours may be produced by a formed tool on the turret or cross slide, or by means of an attachment using a single-point tool so arranged that it will follow a specified form and reproduce this on the work. Attachments for producing angular and curved surfaces are applied in many kinds of manufacturing work to engine or turret lathes. They are often used in combination with other tools for turning, boring and facing; and they may be operated simultaneously or separately, according to the requirements of the work.

Tapered and curved surfaces do not always require a generating action to produce them within the required limits of accuracy. For small work, forming tools of various kinds or tapered reamers can often be used with success on certain kinds of materials, such as cast iron, brass and steel of low carbon content. Alloy steels containing nickel and chromium usually require a generating attachment with a single-point tool, because the "wirey" character of the material does not lend itself readily to formed cuts with wide-faced tools.

Conditions occasionally require more tools than the turret faces will permit; and in such cases it may be necessary to design

a special attachment to be applied to the face of the turret, such that two or more tools can be used by indexing the attachment. This procedure is not necessary very often, but there are times when a special attachment can be used to advantage and thus avoid the necessity of an extra operation. Several important points in connection with the design of attachments are given in the following paragraphs.

(1) The material to be cut determines to some extent whether a generating tool is required or whether simple forming tools can be used. This matter should, therefore, be considered first, as it is a determining factor in the design. The accuracy required is also important, and for a rough job requiring only a clearance cut, a simple forming tool can sometimes be used even if the material is unsuited to this kind of cutting.

(2) The number of pieces to be machined is important, as on small production it hardly pays to design a generating attachment unless great accuracy is required. Therefore, the simple formed tool will often be found more economical on low-production work.

(3) The type of machine used should be selected with care, always considering any other operations which can be performed in the same setting. When a form cut is to be made that cannot be combined with any other operations, it is often possible to adapt an old engine lathe, applying to it the necessary forming or generating attachment. Attention should always be paid to the type of machine most suitable, in order to combine operations and obtain maximum efficiency in this way. Before attempting to design any generating or forming attachment, complete data should be obtained regarding sizes of the various parts of the machine to which the attachment is to be applied.

(4) The rigidity of any tool used in production is an important factor. This is a point which is often overlooked in design; and as a consequence very light cuts must be taken in order to avoid chatter, and much time is therefore lost. Sliding or moving members must be rigidly supported and of sufficient section to withstand the cutting strains. A generating or forming attachment usually has moving parts which must operate freely, yet at the same time there should be no looseness or weak members which would tend to cause vibration.

(5) The convenience of the operator should be studied when designing fixtures In connection with the setting of the tools

and the adjustment of them, the setscrews should be suitably placed so that they are easy of access. If tapers are to be produced by a generating attachment, the taper bar should be easily accessible; if adjustable, suitable provision should be made so that proper measurements can be taken of the angle of the taper. Other points in connection with convenience of operation will be taken up during the treatment of taper and forming attachments.

(6) The flexibility and up-keep of generating attachments should be very carefully considered when designing. There are cases when a tool must be designed to operate in a confined situation, and where there is little chance to make it adjustable so that other sizes can be handled. In many instances, however, a little forethought on the part of the designer will enable him to design the attachment so that it can be used for a considerable range of work. It is very disappointing to find that a slight change in the design of the part requires an entirely new generating fixture, particularly if it appears that the tool could originally have been designed with greater latitude and at practically no more cost.

In providing for up-keep, it is important to make sure that all surfaces subject to wear should be so arranged that replacements are possible, in order that the tools can be kept in good condition for a long period of time. Adjustable gibbing should be provided wherever necessary. The cutting tool itself should be conveniently replaceable, and a suitable gage should be furnished for setting it to the correct size if the conditions of the work require it.

Duplex Attachment.—Mention has been made of the occasional necessity of using more than one tool on a single turret face. While this condition is not often found, yet it is frequent enough to deserve consideration. When the addition of one tool to a turret "set-up" will avoid the necessity for a second operation, it is obvious that a considerable saving can be effected by the use of an attachment which will permit the extra tool to be used along with the others.

In Fig. 146 is shown an attachment of this kind at *A*. The body of the tool is furnished with a shank *B* which fits the turret hole. An indexing member *C* is held in the body of the tool in such a way that it can be readily indexed. Two holes are provided at *D* and *E* to receive the tools required. The illustration at *F* shows the application of the device to a turret set-up.

The tap G and counterbore H can be used progressively on a single turret face. The dotted lines at K indicate the position

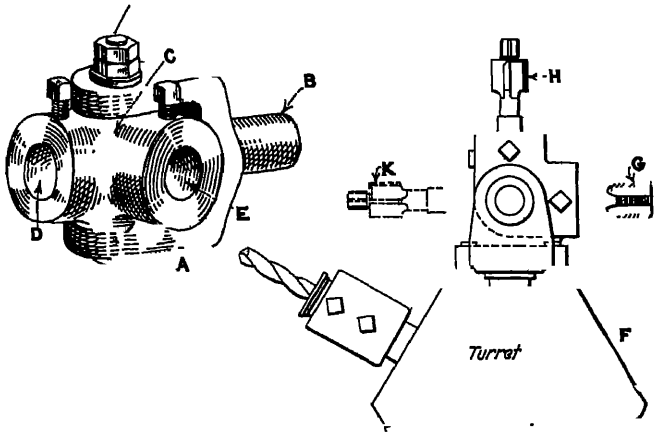


FIG. 146.—Attachment to hold two tools on one turret face.

of the counterbore while the tap is being used. A 90-deg. indexing movement is used on this attachment, and suitable stops and

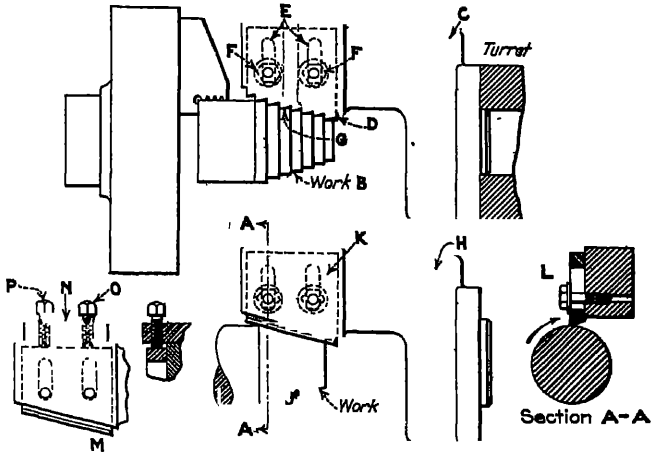


FIG. 147 —Taper-forming tools on turret

an index pin are provided to give the correct location when indexing.

Mention has been made of the possibilities of forming certain kinds of materials with a plain forming tool. We have taken up

previously the design of circular forming tools and other tools of a similar kind used on the cross slide. It is often possible to design a tool for taper work in such a way that it can be applied to the turret of the machine. Tools of this nature are not generally adapted to alloy steels or other materials of a tough and "wirey" nature.

In Fig. 147 is illustrated the application of roughing and finishing tools for a piece of tapered work shown at *B*. The holder *C* is a casting which is fastened to the turret in some convenient manner. The forward end of this body is faced off at the rear so that the cutter *D* can be mounted upon it as shown. Adjustment for diameter is allowed by the two slots at *E*, and the cutter blade is held in place by the setscrews *F*. By mounting the cutter at the rear of the body of the tool, all of the thrust of the cut is taken by the solid member and no great strain is imposed on the setscrews. The angular edge of the tool is serrated at *G* so as to make the cutting action easier and break up the chip.

The finish operation on the taper is done by a tool of similar form, shown at *H*. The body of this tool contains a single cutter blade *K*, which has a plain edge for finishing the work. The adjustment of the tool is made in the same manner as that previously mentioned. The sectional view at *L* illustrates the simplicity of this design, but it will be evident that no provision is made for fine adjustment, the operator being obliged to adjust the tool by the "sledge-hammer" method. Both roughing and finishing tools are tongued, so that they fit the tool body and are thus kept in alignment.

A refinement of this design which permits more accurate adjustment to be made, is shown at *M*. A plate *N* is fitted to the top of the block, and contains two adjusting screws *O* and *P* by means of which the cutter can be readily adjusted to a given diameter. This type of taper forming tool is simple in design and economical in manufacture. For low-production work on suitable materials it can often be used to advantage.

Adjustable Taper-Turning Tools.—For light cutting when it is not necessary to remove a great amount of stock and when the work is of small diameter, an adjustable turning tool like that shown in Fig. 148 will often be found useful. The holder *A* has a shank *B* which fits the turret hole. On the body of the tool a swiveling unit *C* is mounted so that it can be swung and clamped in different positions, according to the angle of taper required.

The body of the tool is graduated at D to assist in setting. The member E is dovetailed to fit the swiveling member C and an adjustable gib is provided at F in order to take up wear. The tool G is conveniently mounted in the slide E and clamped in place by means of a strap H. The slide is moved by means of a rack and pinion, the latter being operated by a handle K. The device is furnished with an adjustable stop L, which can be set to control the travel of the slide.

The application of this tool is shown at M; the work N has a short and blunt taper cut on it. It is necessary only to adjust the swivel to the correct angle and operate the slide by hand

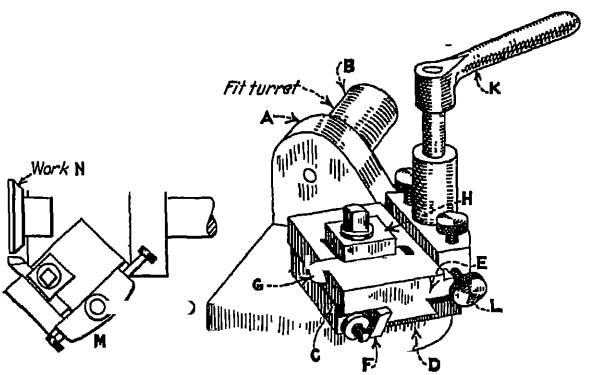


FIG 148.—Adjustable taper-turning tool.

when generating the taper. The advantage of this tool is in the adjustable feature, and also in the fact that it is a self-contained unit which does not interfere with any other tools. For certain kinds of work where the same taper is to be produced continually, a device of this kind can be made up without the swivel member. The taper of the slide is made to suit the work for which it is intended. This simplifies the construction slightly, but there is no chance for adjustment.

When forming or generating attachments are used, there is generally a spring or weight by means of which the roller or follower is kept in contact with the form which is to be reproduced. The direction in which the pressure is applied is important, and there are many forming attachments designed which are incorrect in principle, yet which will many times produce good work if the material being cut is not too hard. The form which

controls the shape of the cut should be so placed that the follower can never lose contact with it under any circumstances.

This matter is illustrated in Fig. 149, and the principles shown there should be clearly understood before attempting to design

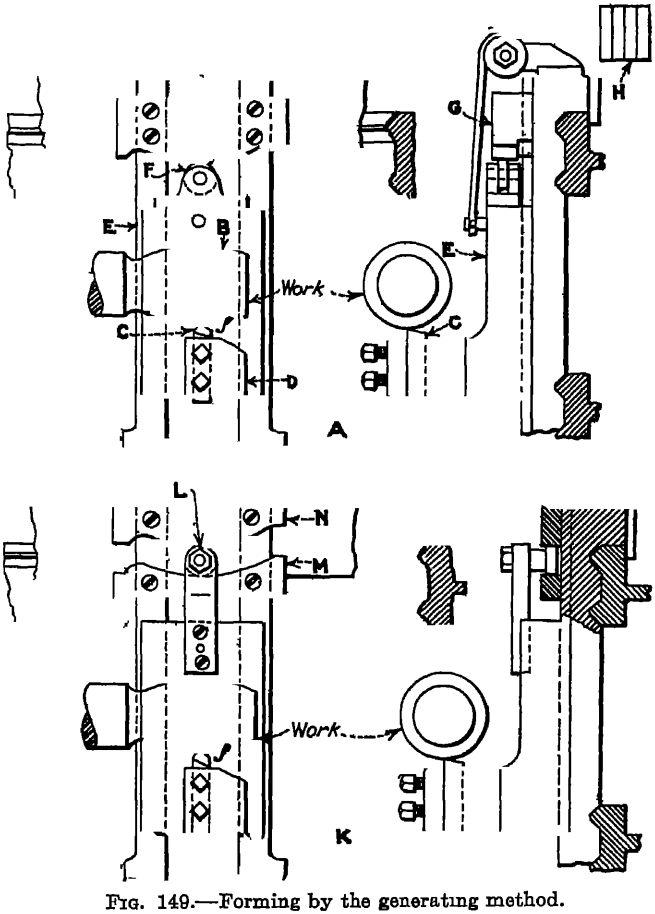


FIG. 149.—Forming by the generating method.

forming attachments. In the example at *A* the work *B* has a curved contour, which is to be generated. The tool *C* is held in a block *D* mounted on a floating slide *E*. At the end of this slide there is a roller *F*, which is kept in contact with the form *G* by means of a weight *H* or a stiff spring. If this weight should not be sufficiently heavy to keep the roll in contact with the form at all times, the tool *C* might be forced out of its position due to

the hardness of the material, so that a true contour would not be obtained. If the work to be machined is a casting and many hard spots are encountered, the finished work is especially likely to be inaccurate.

A method which can be depended upon to reproduce the form accurately, no matter whether the work is hard or soft, is shown at *K*. In this case the pressure is applied against the roll in the direction indicated by the arrow at *L*, so that the roll is continually against the plate *M*. There is a guard plate *N* used simply to prevent any drawing-in action of the tool into the work. This guard plate is seldom necessary, except in cases of very severe cutting or where the pressure of the cut, due to its shape, is likely to overcome the pressure of the spring or weight. The pressure of the work against the tool assists the spring or weight to keep the roll in contact with the form *M*, so that an accurate shape is produced.

In considering the use of springs or weights, it will generally be found more convenient to use springs, as they are less likely to be in the way. The springs should be proportioned so that they will give sufficient pressure to hold the roll firmly against the form plate. The principles indicated in this illustration are fundamental in their nature and are not to be considered as hard and fast rules. For various reasons it may be found necessary to make forming attachments which are not strictly correct in principle, yet which will give good results under the conditions where they are used. The designer must be governed by the shape of the form and the amount of material to be removed.

Generating a Taper.—The method used for generating any sort of a taper should avoid tying up the machine so completely that other tools cannot be used. It is possible to prevent this trouble by employing a very simple arrangement, such as that shown in Fig. 150. The work *A* has a 30-deg. angular surface, which is to be turned, but which is too wide to machine properly with a flat-blade tool. As other tools are to be used in connection with the turning operation, it is desirable to leave the turret and cross slide free, so that they can be used for other tools.

A bracket *B* is mounted on one of the faces of the turret. To the under side of this bracket a hardened steel plate *C* is adjustably fastened. This plate pivots on the bolt *D*, and it can be set to any angle within its capacity after loosening the nut

E. A special holder carrying a roller *F* is located in one face of the cross-slide turret toolpost *G*, and a tool for turning the taper is provided at *H*. Other tools are used in the turret toolpost at *K* and *L* for other operations on the work. When using this attachment, the roller *F* is held firmly against the side of the plate *C* and the crossfeed of the machine is thrown into engagement, thus causing the tool to travel along the angle at which the taper plate is set. An arrangement of this sort will be found very convenient for many kinds of taper work and its simplicity and ease of adjustment make it extremely useful.

Holes of large diameter which are to be bored to a taper are

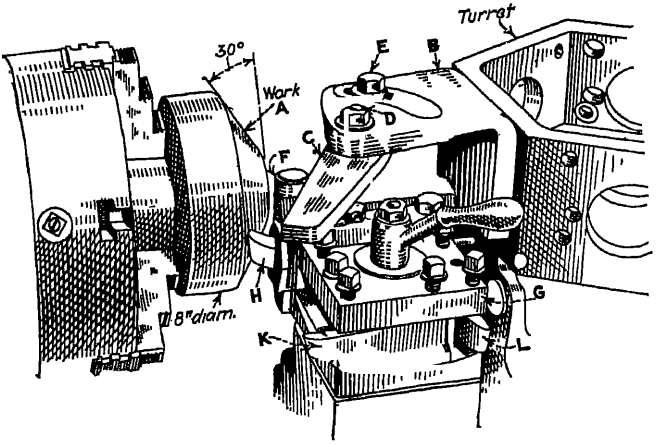


FIG. 150.—Simple method of generating a taper.

most conveniently machined by means of a taper attachment. An example of this kind is shown at *A* in Fig. 151. The inside surface *G* is to be bored to an angle of 20 deg., and it would not be good practice to attempt to do this with a flat-blade tool or anything in the nature of a reamer. The holder *B* is mounted on the face of the turret, and on the upper face of it the bracket *C* is fastened, being held in place by four bolts *D*. The slide *E* is fitted to a dovetail on the face of the bracket *C*, and the spring *F* exerts pressure on the overhanging lug *H*. The amount of this pressure can be regulated by adjusting the locknuts at *K*. A sectional detail of the slide with a tapered gib is shown at *L*.

On the under side of the tool holder *M* a block *N* is fastened in such a position that it carries a hardened roller *O* that is used to control the movement of the slide. A detail of the roller and

holder is shown at X. The body of the tool B carries a pilot bar P, the small end of which Q enters the bushing R in the chuck. A ball thrust bearing S is suitably mounted on the pilot bar so that it strikes the face of the bushing. The upper part of the bar is cut away at T to the angle which is to be generated. The bar is a sliding fit in the body of the tool, and a heavy coil spring U is utilized to keep the pilot in position against the face of the bushing R. In order to prevent the bar from turning, the keyway is cut at V and a special screw W is inserted in the slot.

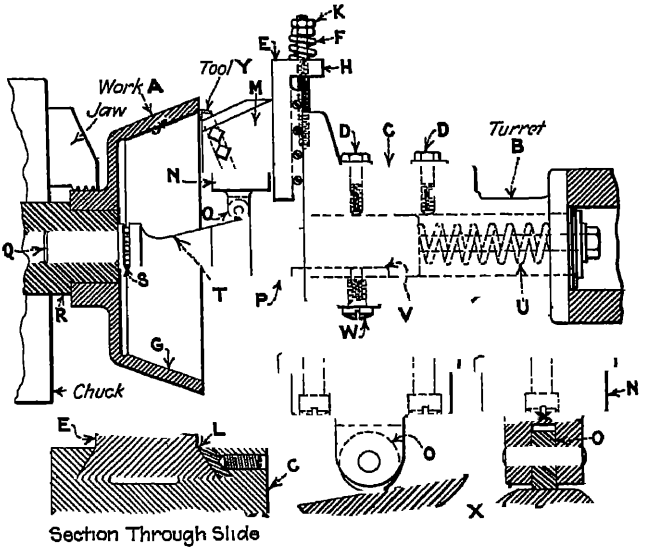


FIG. 151 —Generating tool for boring taper hole

In operation, the device is entirely automatic after the turret feed has been engaged. The ball thrust bearing S remains in position against the face of the bushing, and the body of the tool carrying the slide moves forward while the bar remains still. The pressure of the spring F forces the roller O down against the tapered portion T, thus causing the tool Y to generate the taper according to the angle on the bar. This type of taper boring tool can be applied to either a hand or automatic machine. Adjustments for diameter within the capacity of the attachment are easily made by moving the tool.

Care should be taken in the design of tools of this sort to make sure that all parts are sufficiently heavy to withstand the cutting

action. Replacements of tools should be provided for, and readjustments for wear. The pilot and thrust bearing are very important, as the former assists greatly in supporting the tool, while the latter reduces friction. Bars having different tapers can be substituted for the one shown if it is desired to cut other angles.

A special taper attachment, useful when a number of different tapers are to be turned is shown in Fig. 152. This tool is not of the adjustable type, but the taper bar is readily removable so that it can be replaced by another of a different taper. The

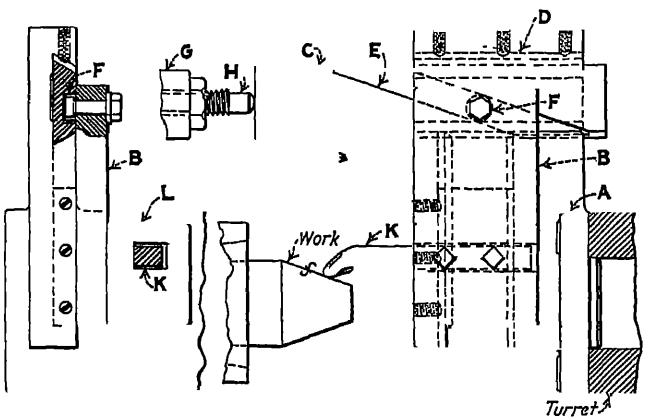


FIG 152.—Special attachment for turning tapers.

body of the tool *A* is in the form of a bracket which is attached to the face of the turret. On this bracket a dove tailed slide *B* provided with a taper gib is mounted. The upper part of the bracket is also dove tailed and a taper bar *C* is fitted to it. An adjustable gib *D* is provided for this dove tailed member also.

The angle of the taper is determined by the angularity of the slot *E* which is cut in the taper bar. The back of the slide *B* has a roller in it at *F*, traveling in the slot *E* and thus controlling the angle of the taper. In some convenient place on the headstock of the machine a bracket *G* is fastened, with an adjustable stop *H* projecting from it a distance sufficient to strike the end of the taper bar as shown. The tool *K* is carried in the block *L* mounted on the vertical sliding member *B*. In operation, the turret is brought forward until the bar *C* strikes the end of the stop *H*, at which time the feed is engaged and the tool moves

ahead controlled as to its angle by the position of the roller in the slot E.

There are some points in this design which can doubtless be improved; for example, the projection of the tool K is excessive and the cutting action would be likely to cause it to dig in and chatter. It would be possible to build the entire mechanism in such a way that the tool would not overhang so much, so that

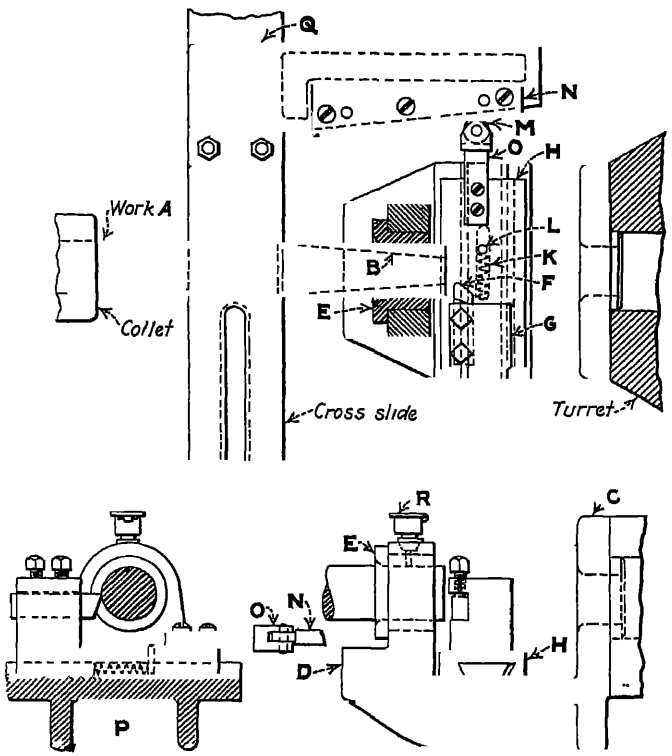


FIG 153.—Taper generating tool with support for work

there would be less danger of vibration. For light cutting, however, when a number of different angles are to be machined, a tool of this kind would produce good work.

The principle here shown can be applied to other varieties of taper turning tools. It would be possible, also, to make a similar arrangement for boring, although the tool holder and slide might be somewhat changed from the form shown. Another improvement on the same tool would be fitting the tool block L in such a

way that it could be adjusted up and down to take different positions on the slide, thus increasing the capacity of the attachment.

When work is long and slender it is difficult to turn it without support; hence a taper turning tool designed for a purpose of this sort should provide the necessary rest for the work. In the work shown at *A* in Fig. 153 a taper is to be cut on the end *B*, as shown by the dotted lines. On account of the length of the bar and the lack of center support, the tool itself must be so arranged that the work cannot vibrate during the cutting action. The body of the tool *C* consists of a bracket fastened to the turret face as shown. At the forward end of this bracket an angular block *D* is located, in order to carry the supporting bushing *E* in which the work is piloted.

The tool *F* is mounted in a block *G* which is fastened to a dovetailed slide *H*. On the under side of this slide the stud *L* is fixed; and the spring *K* thrusts against this stud and causes the roller *M* to remain in contact with the taper blade *N* along which it travels. The roller is supported in a holder *O* fastened to the top of the slide. The illustration at *P* shows this construction clearly. The taper blade *N* is fastened to a substantial bracket *Q* at the rear of the cross slide. The latter is firmly clamped in position longitudinally while the work is being done. It would be possible to attach one or more tools to the front of the cross slide and use them for other operations on the work if necessary. In the present case, however, these tools are not needed as the cross slide is not in use.

An additional refinement which would probably improve this design somewhat would be to make the bracket *Q* shorter, and provide the cross slide with a hardened block over which the bracket *C* can slide, thus giving additional support. Changes would need to be made in the design of the bracket in order to provide for a condition such as this. Vibration is eliminated by the support which the work receives in the bushing. For shallow taper work an attachment of this sort is very useful, and if provided with suitable adjustments a number of tapers could be easily turned, and different diameters of work could be supported by using different sizes of bushings. An oil cup *R* is used to lubricate the bushings.

Many engine lathes are provided with a taper attachment placed at the rear of the machine and usually adjustable within

a limited range. All engine lathes, however, are not provided with an attachment of this kind, although it may be desirable to use one of the machines occasionally for taper work. A simple attachment which can be used for this purpose is shown in Fig. 154.

The work *A* is held in a collet in the usual manner. The regular cross slide of the lathe is removed and replaced by a special slide *B*. This slide is fitted to the dovetail on the carriage

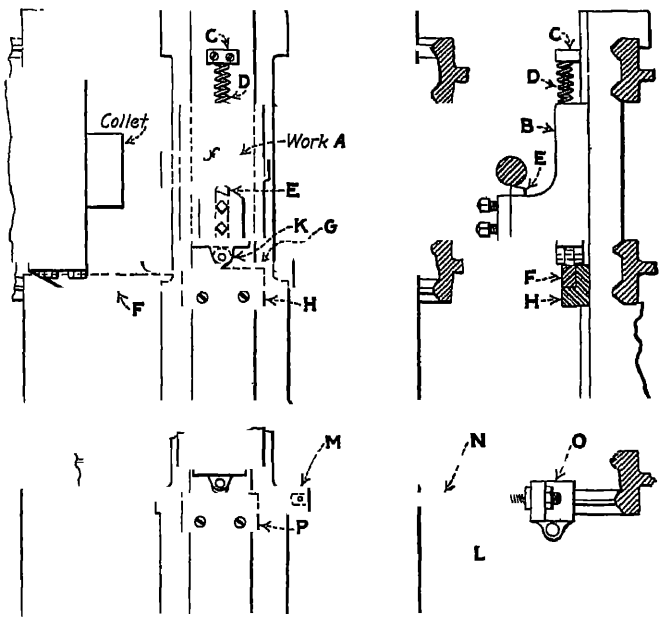


FIG. 154.—Simple taper attachment for engine lathe.

and a block *C* is so fastened that it supports a heavy coil spring *D*. The tool *E* is held at one end of the slide *B* in the proper position with respect to the center of the work. The tapered bar *F* is fastened to the headstock of the lathe, and is machined at *G* to an angle corresponding to the taper required. A block *H* is fastened to the carriage to act as a support for the taper bar and to prevent it from being distorted by the pressure of the roll *K*, which is fastened to the slide.

In order to produce the taper it is only necessary to engage the longitudinal carriage feed, after which the roll travels along the taper bar and thus generates the taper. If for any reason it is

inconvenient to attach the taper bar to the headstock of the machine, it may be applied as shown at *L*. The bar *M* is here attached to a rod *N* carried by the bracket *O*, which is fastened to the ways of the machine. The taper bar in this case is supported by a block *P* arranged in the same manner as that previously mentioned.

Taper work can be done by using the compound rest swung to the proper angle on an engine lathe, but when this is done it is necessary to feed the tool by hand. A turret lathe has no compound rest, and yet it is often desirable to use the cross slide

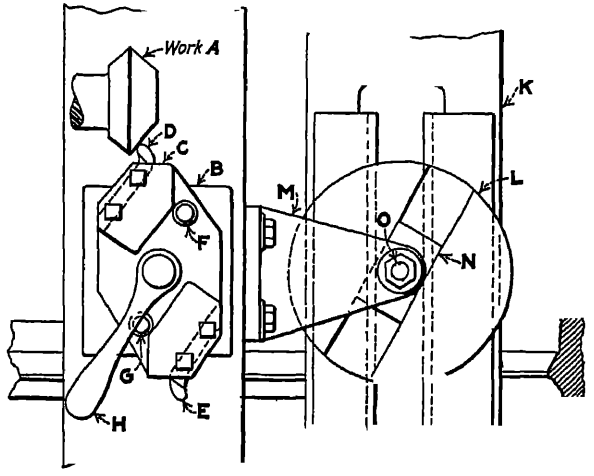


FIG. 155.—Taper turning with the cross slide.

for turning a taper. The attachment shown in Fig. 155 can be used on either an engine lathe or turret lathe; the details of its application are slightly different in each case, but the principle remains the same. The work shown at *A* is to be beveled to an angle of 30 deg. and other work is to be done on it in the same operation. It is therefore desirable to do the work with the cross slide and thus leave the turret free for other tooling.

A special block *B* is mounted on the cross slide of the machine, and to it is fitted an indexing tool holder *C* somewhat similar in general construction to that described in a previous article. The tool *D* is used for roughing the angle, while that at *E* does the finishing. These tools are of the ordinary forged variety, so that they can be easily reground or replaced when worn.

This turret toolpost indexes into only two positions, and these locations are controlled by a plunger in the bushings shown at *F* and *G*. A binder handle *H* locks the toolpost in either position.

The bracket *K* is fastened across the ways of the machine, and on this bracket is mounted a swivel plate *L* which is so arranged that it can be adjusted in a transverse direction. The angle can be changed by simply turning the disk around to the required position. Graduations for various angles can be conveniently placed on the base of the swivel, in order to make the setting easier. The cross slide is provided with a bracket *M*, at the end of which is a block *N* pivoted on a stud at *O*. This block travels back and forth in the slot in the plate, thus controlling the angle of the taper. It is evident that the cross slide must be left free longitudinally, so that it can adjust itself to allow the tool to follow the angle of the taper. After the cross-slide feed is engaged, the action of the device is automatic.

If a number of pieces of work are to be machined to various tapers and if the pieces are similar in their general shape, it is quite possible to design a taper-turning attachment with removable taper bars so that all of the work can be handled with the same attachment. When a designer is called upon to develop something along these lines, it is necessary first to determine the largest and smallest diameters which are to be machined. With this as a starting point, the range or capacity of the tool is predetermined; and it is only necessary to make sure that the methods of holding are uniform, in order that the method of machining will be similar in each case.

Progressive Design of Taper-Turning Attachment.—An excellent example of a progressive design of taper-turning attachment suitable for turret lathes is shown in Fig. 156. This attachment was designed particularly for handling a number of sizes of beveled pinions similar to the one shown at *A*. These pinions were of different diameters and tapers, and it was necessary to make the attachment in such a way that the angular surfaces would be generated accurately and without the necessity for making adjustments to take care of the different angles. The only way in which this could be done with certainty was to use separate taper bars for each angle, thus avoiding any chance of error which might otherwise be caused by a faulty setting.

The tools were designed for both roughing and finishing operations, two attachments being used on opposite sides of the turret. Only one of these attachments is shown in the illustration. The

work A is held on a special expanding arbor B in the nosepiece C screwed to the end of the spindle. The body of the tool D is fastened to the turret face. Another tool body of exactly the same shape is on the opposite face of the turret; and a tie member E extends entirely across the turret and holds the tool bodies together, thus making a very rigid construction.

The slide F is held in place on the body by two flat straps G

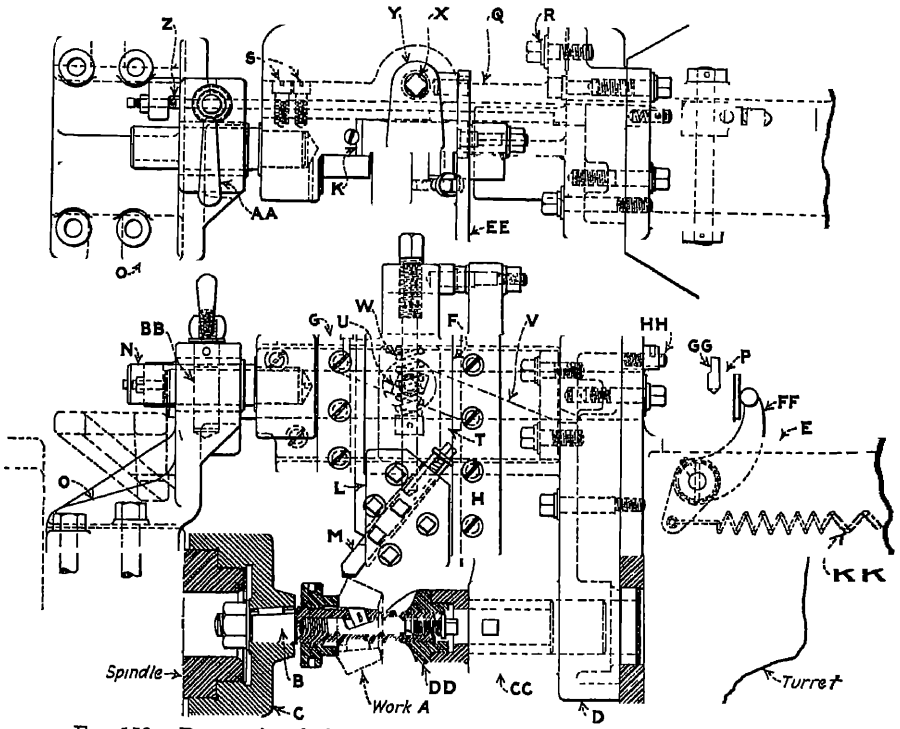


FIG. 156.—Progressive design of taper-turning attachment for turret lathes

and H, and a taper gib K is provided on the side opposite to that taking the thrust of the cut, as shown at K. A separate tool block L is fastened to the slide by means of suitable screws. This tool block carries a turning tool M which generates the taper. The forward end of the tool body is fitted with a pilot N which enters a bushing in the bracket O on the headstock of the machine. This construction tends to stabilize the whole attachment when in operation. It also assists in obtaining accurate work, as it preserves the alignment so that there is no chance for variation.

Removable Taper Bar.—The taper bar *P* lies in a slot machined at the back of the body of the tool. For convenience in machining the body is entirely open, but ribs on the top and bottom extend out and give greater rigidity. A reinforcing member *Q* is fitted between the ribs mentioned and bolted to the body of the tool at *R* and *S*, thus tying the units together and making them still stronger. There is a cored opening *T* at the rear of the slide; and the swivel block *U* projects through this opening, thus entering and being guided by the angular slot *V* in the taper bar. This construction is shown by the dotted lines. A heavy coil spring *W* is used to keep the block in contact with the slot in the taper bar. Adjustment for pressure is obtained by moving the special screw *X* up or down as may be required. This screw is threaded into the overhanging lug *Y* in the slide.

The bracket *O* is slotted at one side to hold the taper bar. An end stop *Z* makes it possible to obtain fine adjustments for the bar, so that the angular portion will be in the right relation to the slide. The binder handle *AA* is threaded to the top of a cylindrical plug *BB* through a slot in which the taper bar passes. The various members of this attachment are cored out wherever possible in order to reduce the weight, but there is no sacrifice in rigidity.

Method of Operation.—In operation the turret is brought forward until the pilot on the attachment enters the bushing in the spindle cap bracket *O*. It is carried forward sufficiently so that the end of the taper bar strikes the stop at *Z*, after which the binder handle *AA* is tightened. The feed is then thrown into engagement, and the tool moves forward while the taper bar remains still. The slide is controlled by the swivel block U which rides in the taper slot *V*, thus causing the tool *M* to generate the taper on the work. The hub *CC* on the body of the tool contains an angular face mill *DD* which is used to remove the stock from the cupped surface at the end of the gear blank.

After the taper has been generated, the binder handle is loosened and the entire mechanism drawn back away from the work. When this has been done the operator pulls down on the handle *EE*, thus relieving the pressure on the spring which controls the slide. This allows the kicker *FF* to act against the end of the taper bar, moving it forward until it is restrained by the pin *GG* coming in contact with the spring bumper *HH*. The coil spring *KK* exerts the pressure on the kicker. The turret can

now be indexed and other tools brought into use on the work. The final cut is made by another taper turning tool exactly like this one.

The possibilities of this tool cover a wide range. The device was so designed that the tool block L could be removed and a boring tool holder substituted for it, so that tapers could not only be turned but could also be bored to any size within the range of the attachment. Taper bars of various angles can be easily substituted to handle different pieces of work. The accuracy

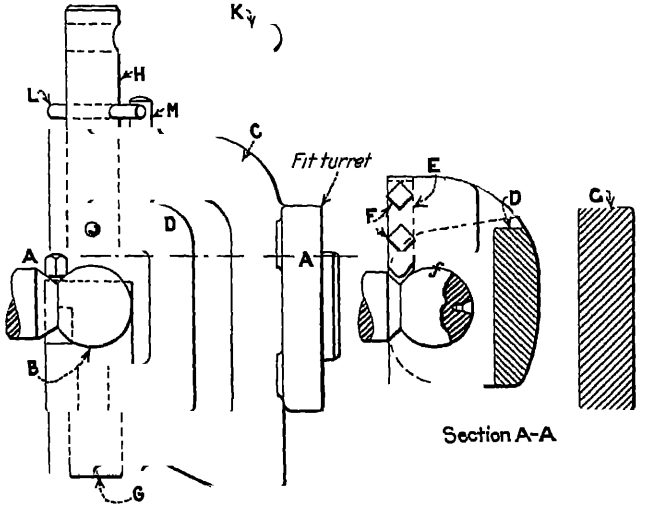


FIG. 157.—Spherical turning device.

obtained on taper work with a device of this sort is fully equal to that which can be obtained on an engine lathe with a taper attachment. Attention is called, however, to the provisions made for adjustment and for handling various diameters of work. Naturally, as tools of this sort are somewhat expensive, it would not be economical to make anything of the kind unless the production were great enough to warrant the expenditure.

Attachments for Machining Spherical Surfaces.—In the design of tools for turning spherical surfaces it is advisable, as far as possible, to generate the surface by swinging the tool on a radius of the required size. On small work of brass or of other materials of such a character that they can be readily formed, it is possible to obtain good results by the use of a

formed tool carrier either on the turret or the cross slide. The method previously shown in Fig. 156 can be applied also to the forming of a spherical surface. It is an advantage to make tools self-contained so far as possible, and thus allow other tools to be used in the turret or cross slide in the same setting of the work.

In Fig. 157 is shown a simple form of spherical turning device for the work *B*. The body of the tool *C* is fastened to the turret, and is U-shaped so that it receives a swivel member *D*. This member carries a tool *E* held in place by two setscrews *F*. The swivel is pivoted at *G* in the body of the holder. The upper

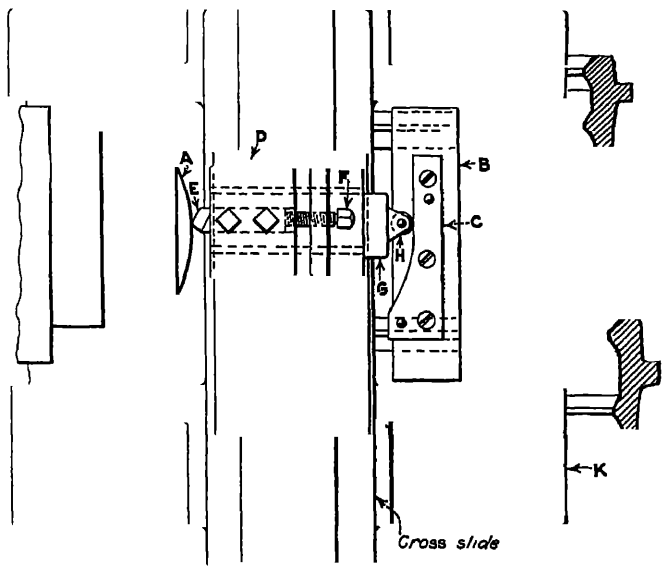


FIG. 158.—Device for rounding the end of a casting

portion is attached to a stem *H* in such a way that it can be readily turned by moving the handle *K*. The stem *H* is fitted with a stop pin *L* which comes to rest against the stud *M*, thus limiting the movement of the tool.

In operation, the workman feeds the tool by hand by grasping the handle *K*, thus generating the surface. Tools of this sort can often be used for small work; but it is important that they should be used as close to the end of the spindle as possible, in order that the work does not have too much overhang and thus cause vibration. Particular attention must be paid in the design to the rigidity of the tool, as no support is provided.

When a forming plate is used for controlling the shape of a curved surface, a very simple arrangement can often be made. An example of this sort is shown in Fig. 158, where the work *A* has the projecting end rounded as shown. This operation does not require a particularly accurate job, yet the stock must be removed and a smooth surface machined. The bracket *B* is attached to the ways of the lathe and carries a forming plate *C* as shown. The cross slide is fitted with a tool block *D* in which the tool *E* is carried. Adjustment is made by means of the setscrew at *F*. At one end of the block the roll holder *G* is fastened in such a position that the roll *H* comes in contact with the form plate.

In operating the device, pressure is applied either by weight or springs in the direction indicated by the arrow at *K*, thus holding the roll firmly against the form plate. The crossfeed

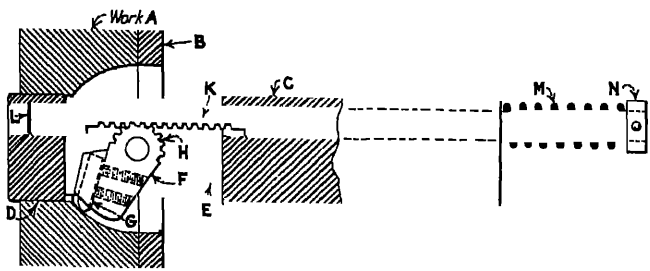


FIG. 159.—Inside spherical generating tool.

screw feeds the tool across the end of the work, and the direction of travel is controlled by the contact of the roll with the plate. A very simple device somewhat cheaper than the attachment can be made by using a form plate carried directly in the tailstock of the lathe. This does not require a special bracket *B*, and it can be made up somewhat more cheaply.

Inside Generating Tool.—Considerable ingenuity is often needed in designing a tool for boring an inside curved surface. A simple device for this purpose is illustrated in Fig. 159. The work parts *A* and *B* are fastened together so that the two pieces are bored at the same time. The body of the tool holder *C* is held on the cross slide of the lathe by a simple bracket. The forward end of the bar is piloted at *D* in the work. A slot is cut entirely across the bar at *E*, and in this slot a swivel member *F* is carried. The tool *G* is inserted in the swivel member and held

in place by two setscrews, as shown. One end of the swivel block is cut in pinion form as indicated at H.

The side of the bar K has a rack cut upon it which engages with the pinion H. The end of the bar L enters the hole at the end of the holder, thus giving additional support. The bar K extends entirely through the holder C, and is furnished with a stiff coil spring at M acting against the collar N. In operating

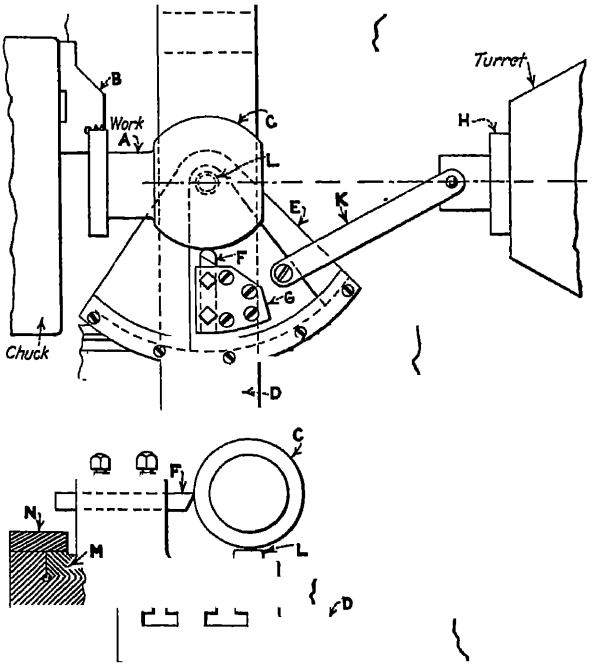


FIG 160.—Curved generating attachment for turret lathe.

the device, the cross slide is moved into position and locked; after which the tailstock is screwed up against the end of the collar N and the feed is obtained by movement of the tailstock screw.

In Fig. 160 is illustrated a device used for turning the spherical surface C on the work A, which is held in chuck jaws B. The surface is generated by a radial movement and not by a form in this case. The cross slide D is fitted with a bracket E on which is mounted a swiveling member pivoted at L. This swivel contains a tool holder G in which the tool F is adjustably held. The

member H is fastened to the turret face and connected with the link K fastened to the swivel. The forward movement of the turret causes the tool to travel in an arc of the desired radius, so that the curved surface is produced by a true generating action.

Care must be taken in designing tools of this sort to make sure that the swiveling member is well supported and gibbed, so that there will be no lost motion or vibration. In the case shown, the swivel is turned circular at M and is held down by means of a circular strap N, which is fitted carefully so that there is no looseness. If required for a large diameter, it may sometimes be necessary to design a special cross slide to hold the turning tools, in order that sufficient support for the swivel member may be obtained. The designer should be very careful to lay out the extreme movements of the swivel in both directions, to make sure that there are no interferences.

Spherical Turning Attachment.—There are numerous cases

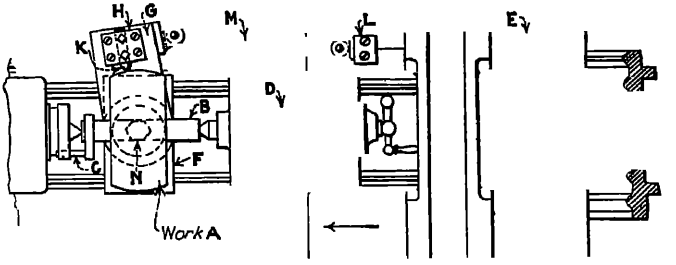


FIG. 161.—Spherical turning attachment for engine lathe.

in which a simple attachment can be made for an engine lathe to turn a spherical surface, such as that shown at A in Fig. 161. The work in this case is held on an arbor B driven by a special dog C in a slot in the faceplate. The outer end of the arbor is supported by a center in the tailstock D. The ordinary positions of the carriage and tailstock are reversed when using this fixture, as the tailstock is placed between the carriage and the headstock.

A special bracket F is fastened to the ways of the machine directly under the work, and on this bracket a swiveling member G is mounted. This member carries a tool block H in which the tool K is supported. The tool block H is so arranged that it can be adjusted readily toward the center pivot N, so that various diameters can be turned. The carriage E has a block L fastened

to it and connected to the link M, the other end of which is attached to the swiveling block G. It is only necessary to set up the work in the desired position and use the longitudinal carriage feed in the regular way. The tool K then travels on the circumference of a circle, the size of which depends upon the distance the tool is set from the center.

The operation of this device is very simple and the design is economical with regard to construction cost. In the example shown, the tool K is at the rear of the lathe so that there is a lifting cut upon the swivel. It would probably be better to arrange it so the tool is at the front of the lathe, as the pressure of the cut would then be downward instead of upward. The general details of the arrangement would be the same in either case.

Combined Curved and Straight Turning.—It is rather difficult

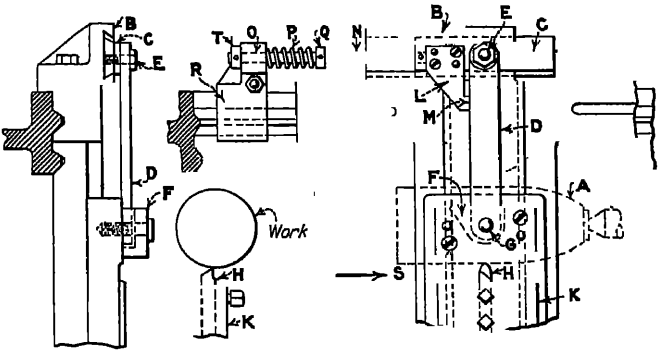


FIG. 162.—Combined curved and straight turning attachment.

to turn a given diameter so that it becomes perfectly tangent to a curved surface on the same piece of work. In the example shown in Fig. 162, the end of the work is turned to a radius A which becomes tangent to the outside diameter and forms a continuation of it In order to make sure that there would be no interruption or shoulders on the work, it was decided to develop an attachment in which the same tool would cut the radius and turn the outside diameter.

The work is held on centers in an engine lathe, and the regular cross slide is removed from the carriage. A special bracket B is bolted to the back of the carriage, as shown, and in this bracket a dovetailed member C is fitted so that it will slide freely in a longitudinal direction. A link D of the proper radius is pivoted

at E on the sliding member. The other end G is pinned to the block F, which is attached to a special toolslide K fitted to the dovetail on the carriage. This toolslide carries a turning tool H held in place by setscrews and furnished with a back-up screw for fine adjustment. The latter is not shown in the illustration.

The block L is fastened to the sliding member C in such a position that the shoulder M acts as a stop against the radius bar D

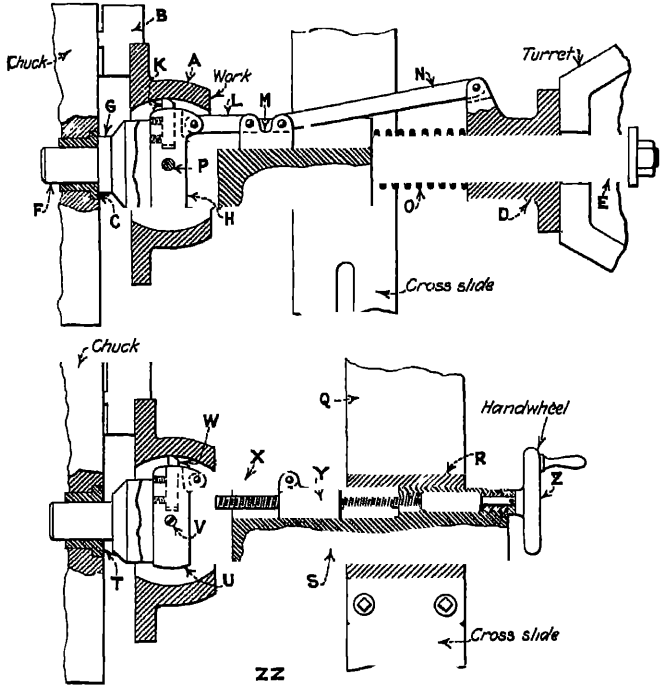


FIG. 163.—Two methods of boring an inside curved surface.

at the completion of the radius-turning movement. The rod N is fastened to the end of the slide C, and passes through a bracket R which is securely fixed on the ways of the lathe. The spring P thrusts against the collar Q pinned to the shaft, which latter is a sliding fit at O in the bracket mentioned.

In operating the device, the carriage is fed in the direction indicated by the arrow at S, and the radius rod remains in contact with the stop M while work is being turned cylindrical. When the collar T strikes the edge of the bracket R, the cylindrical turning operation ceases and the radius turning starts. It is evident that

the movement of the member *C* is arrested at this point, so that the motion of the slide is controlled by the longitudinal feed of the carriage and the tool *H* travels about a center as constrained by the bar *D*, thus completing the work.

In generating a radius on the inside of a piece of work, the tools used for the purpose are affected very largely by the size of the work and the accuracy required. When a condition like this is found, great care must be taken in the design of a generating tool to make sure that it has sufficient rigidity to withstand the pressure of the cut. A support for the end of the bar in which the generating attachment is contained is of great importance.

In Fig. 163 is shown a piece of work *A* held in chuck jaws *B* on a turret lathe. The inside curved surface is to be generated to a true spherical form. The chuck is furnished with a bushing *C* which acts as a support for the bar *E* held in a bracket *D* on the face of the turret. The end of the bar *F* enters the bushing, and a collar *G* comes against the face of the bushing and acts as a longitudinal stop, thus positioning the bar.

The boring tool *K* is held in a swivel block *H* in a slot in the bar. It is pivoted at *P*, and a link *L* connects the swivel member with the sliding block *M* which is fitted to a longitudinal slot in the bar. The link *N* connects the bracket *D* with the sliding block mentioned, so that the tool can be fed. A heavy coil spring *O* is placed between the shoulder of the bar and the end of the hub on the bracket *D*. This spring keeps the thrust washer *G* up against the face of the bushing *C* at all times. In operation, the turret is moved forward until the tool is in position ready to start the cut, after which the feed is engaged. The turret then travels forward, carrying with it the bracket *D*, pushing the link *N* along, and thus causing the tool *K* to describe the proper radius.

A somewhat similar arrangement for the same piece of work is shown at *ZZ*. This application, however, is made to an engine lathe. The cross slide *Q*, has mounted upon it a holder *R*, into which the bar *S* is clamped. The end of the bar is piloted in a bushing at *T*, but no stop collar is used. A swivel block *U* is provided with a pivot at *V* and contains the tool *W* which does the boring. This block is connected by means of a link *X* to the block *Y*, which is tapped to receive a threaded rod connected to the handwheel *Z*. By operating this handwheel, the block *Y* travels in the slot to which it is fitted, thus moving the link *X* and causing the tool to travel in the desired direction.

CHAPTER XIII

LAYOUT WORK

METHODS EMPLOYED IN DESIGNING TOOLS FOR TURRET LATHES —USE OF LAYOUTS AND SKETCHES—FAMILIARITY WITH MACHINES NECESSARY FOR THE DESIGNER—DIFFERENT WAYS OF DEVELOPING THE DESIGN—DETAILED LAYOUTS FOR PULLEY AND BEVEL RING GEAR

The methods of manufacture used on turret lathes should be determined by the tool department, and not by the department foreman. If the tool department has not sufficient knowledge to do this, a capable man familiar with this class of work should be obtained as soon as possible. Factory procedure varies in this matter; some believe the department foreman the best man to make "set-ups" for various jobs; others believe that the work can be done more profitably by the tool engineering department. We do not wish to argue the points, but will content ourselves with the statement that turret lathe departments in which the work has been properly planned and tooled by a capable tool engineer familiar with this kind of work, show a production far in excess of that obtained when the department foreman is responsible for the methods of tooling.

This statement is not intended to reflect on the department foreman in any way, as his province is not to provide tools and study methods of handling, but rather to produce the work with tools which are furnished to him. Jigs and fixtures are designed by the tool engineer, and there is no valid reason why turret tooling should not be handled in the same manner. As a matter of fact, the principal reason why a turret lathe department foreman is often called upon to make turret lathe set-ups is because the tool engineer has neglected this important phase of his business, and is therefore not capable of doing the work properly.

Lack of specific knowledge regarding the operation of turret lathes is one of the principal reasons why tool engineers often feel "out of their depth" when methods of handling work on turret lathes are to be considered. By consistent study of various

turret lathes and by getting into the shop and operating the machines, a tool designer can soon obtain sufficient knowledge to enable him to grasp the important points connected with the arrangement and use of turret tools. No branch of tool engineering is more interesting and instructive than turret lathe work, and the field is wide enough to allow a capable man to rise rapidly if he specializes along this line.

One of the first considerations in making a turret layout is a knowledge of the machine which may be selected or specified on the operation sheet. In some cases the selection may be left to the tool engineer. Certain types of machines are generally considered better for roughing operations, but there is no good reason for this except the power of the machine; yet we find the opinion prevailing that certain types are unsuited for accurate finishing.

At the risk of being considered too broad in our statements, we say that in our opinion the accuracy obtainable from different types of machines is largely dependent on the tooling, always assuming that the machines themselves are in first-class condition. The tool engineer who is called upon to produce accurate work on a type of machine generally considered suitable for roughing, must design tools so as to take into consideration the possibility of inaccuracies in the machine. This can be done by piloting all tools and providing them with accurate adjustments.

Familiarity with the ratio of cutting feeds and speeds on a given type of machine is of considerable assistance when making a turret layout. The cross-slide and turret feeds are often working at the same time, so that the tools on turret and cross slide are approaching each other. The feeds used can be proportioned so as to avoid interferences. In a grooving operation the cross-slide feed would be much finer than if turning or facing.

The feeds for different materials and in various kinds of cutting operations will be treated separately, but the tool engineer should familiarize himself with the subject in order that his designs may be consistent. Actual shop practice is of great assistance in this regard, and the man with first-hand information, gained by actual work in the shop, has a decided advantage over another not so well posted.

Turning, boring, facing and grooving operations are often done simultaneously in order to obtain maximum efficiency. The highest production is obtained by continuous cutting, thus doing

away with idle time of the machine. In making the tool layout the expert engineer takes special pains to design tools that take advantage of multiple cutting, thus removing the stock as rapidly as possible. On thin work, which is likely to be distorted, it is a good idea to take all roughing cuts before any finishing is done. After the "skin" on the casting has been removed, the internal stresses are relieved and there is less likelihood of distortion in the finishing cuts. If, however, only a part of the work has been roughed off before finish cuts are taken, the work may change slightly after the final roughing cuts are made, thus causing inaccurate work.

The matter of interferences of tools with each other or with portions of the machine while indexing has been mentioned in a previous chapter. The tool layout should be so made that any interferences will be clearly apparent, and suitable remedies can be applied. Care should be taken to show all tools in their actual positions with relation to each other, usually at the completion of a cut.

If turret tools are turning and boring while cross-slide tools are facing, it is advisable to show the turret tools in the position that they would be in at this stage of the operation. In other words, if the turret feed is 0.040 in. per revolution while the cross slide is grooving at 0.007 in. feed, the turret may complete its work before the cross-slide tools have finished. In this case it may be possible to bring up the tools on the next turret face and put them into operation before the grooving has been finished. These points should all be considered in making a turret layout.

The first step in tooling a piece of work on a turret lathe is to make a sketch to show the general method used. This sketch is usually made freehand by the tool engineer, and it is used as a guide in the design of the necessary tools. The procedure varies; some men favor the design of tools first and after this make a layout to scale, while others first make the layout and design the tools from it. The latter method is much to be preferred, but it requires a capable man to make the layout, one who really designs the tools roughly while making the drawing. Such a man, who is thoroughly familiar with the machines on which he is working, can rough out several complete layouts in a day to approximate scale.

In order to carry out this layout work to advantage and obtain the best results, layouts are most commonly made on tracing

paper under which has been placed a scale drawing of the turret, spindle and cross slide in their respective positions. The master drawing may be made to ⅛, ¼ or ½ size, according to preference. The ¼-size layout is often used and will be found all right for a large proportion of the work. Fig. 164 shows a master sheet used for this purpose. If a number of types of machines are in general use, it would be necessary to have a master sheet for each machine. As this sheet is used frequently, it is advisable to make it in ink on tracing cloth. The center lines should be well defined, so that they can be clearly seen when tracing.

In the example, the spindle *A* is shown in section and an

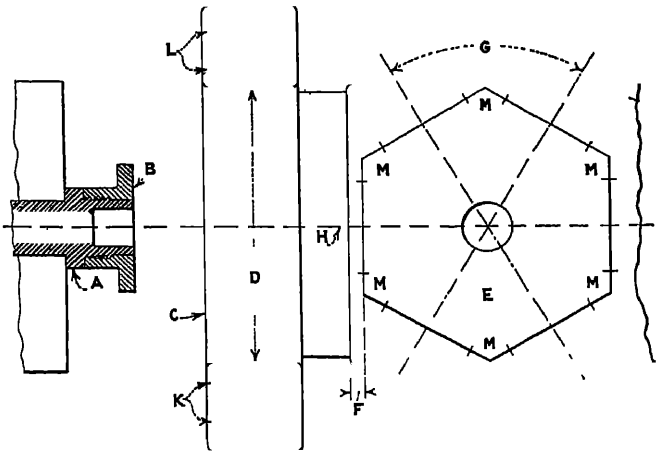


FIG. 164.—Tool engineer's master layout for turret lathe.

adapter *B* of standard form is mounted upon it. It is only necessary then for the tool engineer to place his chuck or fixture in the correct position on the spindle, either screwing it in place or mounting it on the adapter. The cross slide *C* is shown full length, and the distance *D* is laid out according to the dimensions on the machine. T-slots are shown at *K* and *L*, so that when tools are applied to the front and rear of the cross slide they will be in their exact relation to each other.

The turret shown at *E* has all the center lines shown at *G*, in order that tools may be placed in their proper positions. Center lines at *M* on each turret face indicate the position of bolts used to fasten the tools to the faces of the turret. The line *H* is very important, as it represents the center line of both spindle

and turret. On certain types of machines the base of the turret slide extends a short distance ahead of the face of the turret, as shown at *F*. As this projection would strike the cross slide, it should be clearly indicated as at *F* in order to prevent interferences.

A master sheet of this sort is of great help when making turret layouts, and it can be made in a size suitable for the finished layout or for the freehand sketch. There is much less likelihood of errors in proportioning tools when the tool engineer who plans the work has a sheet of this sort to use as a guide. Freehand

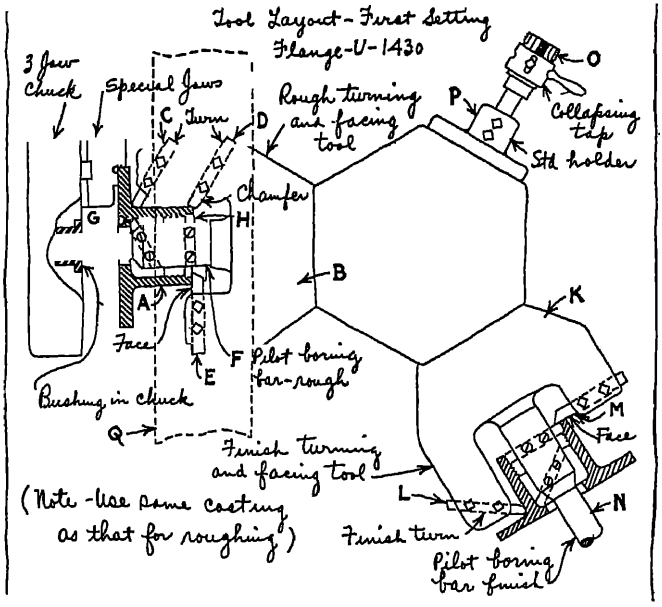


FIG. 165.—Tool engineer's freehand sketch of tool equipment for turret lathe.

sketches are often more or less out of proportion, and this fact sometimes causes trouble when making the final layout.

In Fig. 165 is illustrated a freehand sketch with notes, as often made by the tool engineer. The work shown at *A* is a flange which is to be turned, bored, chamfered, faced and threaded. The turning, chamfering and facing operations are accomplished by using a special turning and facing tool *B*. The tool *C* does the turning, *D* cuts the chamfer on the end of the work and *E* faces the end. A boring bar *F* is piloted in a bushing in the chuck. This boring bar has two tools *G* and *H*, the former doing the boring while the latter cuts a slight recess at the end of the work.

The finishing tool K is provided with turning and facing tools at L and M, respectively, and a finish-boring bar N is used in connection with these tools. The thread is cut by means of a collapsing tap O mounted in a standard holder P. The cross slide of the turret lathe is not used in this setting, but it is necessary to build the various tools with sufficient overhang so that there will

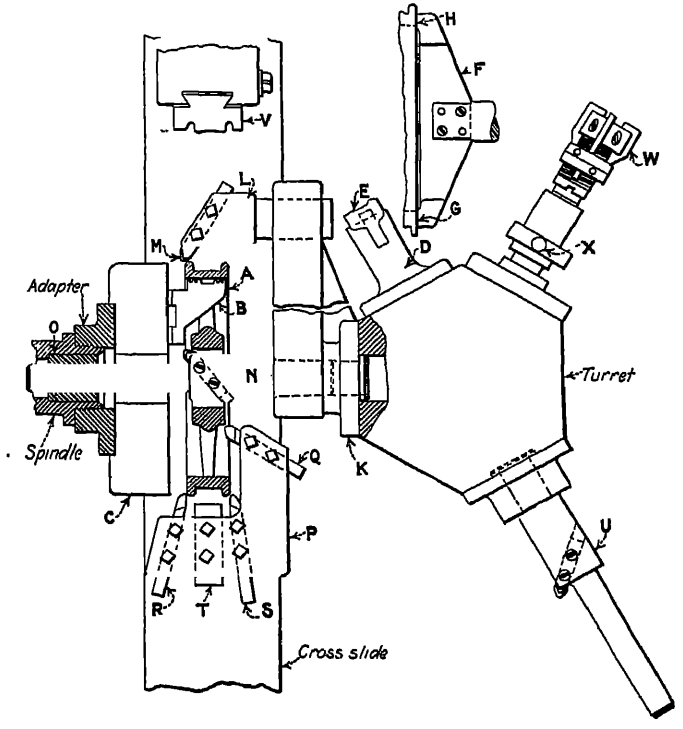


FIG. 166.—Tool layout for grooved pulley.

be no interferences. The position of the cross slide is shown by the dotted lines at Q.

This last point is very well worth thinking about, as it is not at all convenient to remove the cross slide completely on any type of turret lathe and there is not usually sufficient clearance so that it can be moved back out of the way under the chuck. The freehand layout shown contains a number of notes to guide the tool designer in his work. The various tools are briefly specified in writing, so as to make the matter clear to the designer.

In order to make the various points of importance clear with respect to turret tool-layouts, several examples will be given here with explanations to cover each particular case. Fig. 166 shows a tool-layout for a horizontal turret lathe used in machining the grooved pulley *A*. In considering this layout let us first examine the work, noting that both sides of the flange are finished and that the hub is bored and reamed. The grooved portion of the pulley is also finished. It is desirable to complete the work in one setting, and the tool equipment is designed for this purpose.

The work is held by the inside in special jaws *B* in a three-jaw universal chuck *C*. These chuck jaws are cut away so that the facing tools can pass by and finish the edge of the flange without interference. The method of setting up this work is by means of a chucking spider shown at *D*. This spider is so arranged that the portion *E* stands vertically, as shown in the side view at *F*. It bears against the edge of the casting at *G* and *H* and assists greatly in straightening it up while the chuck jaws are being tightened. The work is placed on the jaws slightly in advance of the position which it will take when machining. The jaws are then brought up lightly on the inside of the work, and the turret is moved forward by hand so that the chucking spider comes against the face of the flange and pushes it on the jaws to a distance predetermined by setting a stop on the turret slide. After this the jaws are tightened sufficiently to hold the work.

The holder *K* is fastened to the first turret face and contains a tool holder *L*, in which the tool *M* is used for turning the outside diameter. A boring bar *N* is used at the same time, and the end of this bar is piloted in a bushing *O* in the spindle. The turning tool is really in a vertical position, but is shown horizontally in order to illustrate the action clearly in one view. While the boring and turning operations are going on, a special tool block *P* on the front of the cross slide is used for facing the hub with a tool *Q*. Two other tools *R* and *S* face the sides of the flange, while the wide tool *T* roughs out the bottom of the groove.

The next operation is finish boring of the hole by means of another piloted bar, shown at *U*. While this operation is going on the dovetail forming tool *V* at the rear of the cross slide is put into operation to finish out the groove. The final operation on the work consists of reaming the hole with an adjustable reamer *W* in the floating holder *X*.

The toolholder K is a standard type and can be purchased in considerable variety in the open market. The adjustable reamer is also a standard make, but the other tools shown must be built specially to suit this particular piece of work. It is advisable to use standard tool equipment for turret lathe work when possible, providing the production can be kept up to the maximum. When work is out of the ordinary and heavy cutting is necessary, special toolholders are often required.

The work shown in Fig. 167 requires two turret lathe operations, and both layouts are shown in order to illustrate the method of handling. The base of this casting is square and there are four holes A, B, C and D as shown. In deciding upon

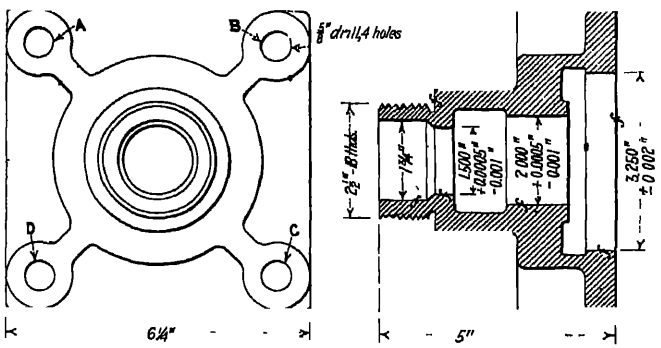


FIG 167.—Work requiring two turret lathe operations

a method of handling, it seems advisable to use a chuck for the first operation if possible, as it makes the setting up so much easier. The holes through the center of the piece must be concentric, yet they cannot all be machined in the same setting. The method of handling, therefore, must consider two settings and the location for the second operation must be such that concentricity in the holes can be obtained.

In Fig. 168 is illustrated the method used for the first setting. The work A is held by the outside of the hub in special jaws B in a three-jaw chuck. End location is obtained by the position of the work against the end of the chuck jaw. The tool holder C is used on the first turret face to hold a double boring bar D, in which are two tools E and F. The bar is piloted in a bushing G in the chuck. While this boring operation is going on, a standard tool holder H on the front of the cross slide is used with a tool K for rough-facing the flange.

The second operation is identically the same as the first, except that the boring bar L is used for finishing two diameters in the hole while the facing tool M finish-faces the flange from the rear of the cross slide. A reference to the work will show the dimension 3.250 ± 0.002 in. This is not a very accurate dimension, but the 2-in. hole is held close to size. In order to avoid the expense of a reamer for the large hole, a special boring bar

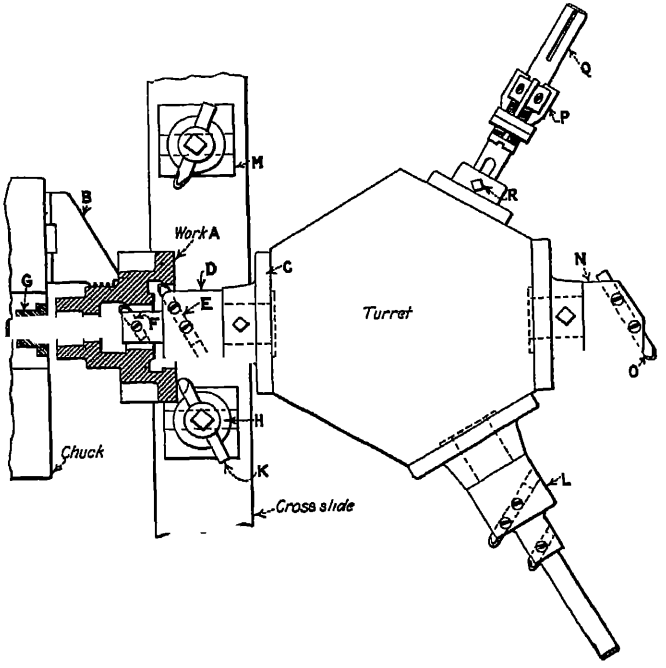


FIG. 168.—First layout for part shown in Fig. 167.

N with a single-point tool O is used for sizing this hole. The final operation on the work in this setting consists of reaming the 2-in. hole with an adjustable reamer P having a pilot Q and being held in a floating holder R.

After the first turret lathe operation, the work is placed in a drill jig and the flange holes A, B, C and D are drilled. This operation is done between the two turret lathe settings in order to provide an effective method of driving for the second operation. It would be possible to do the drilling at another time and use a pin against the side of the casting to assist in driving,

if for any reason the drilling operation would be inconvenient and require a great deal of extra handling.

In setting up for the second operation, the work is located by the plug *A* in the 2-in. hole, Fig. 169. A special faceplate fixture *B* has four hardened studs in it at *C*, and the face of the flange rests on these studs. The work is clamped in place by four straps *D*, and there are two pins (not shown) which enter the holes drilled in the flange and act as drivers. The holder *E* contains a bar *F* in which are two tools for boring the 1.500 and 1¾-in. diameters. This bar is piloted in a hole in the end of the

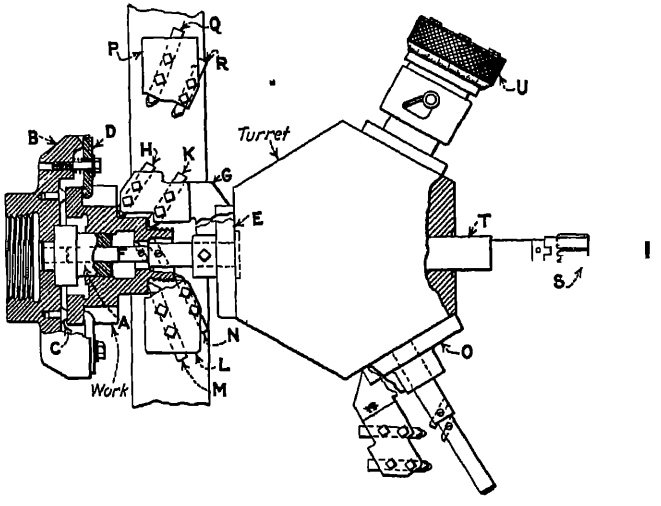


FIG. 169.—Second layout for part in Fig. 167.

locating plug, in order to preserve the alignment between the various holes.

The tool holder *E* has a vertical extension *G*, in which are two turning tools *H* and *K* for turning the outside diameters. This turning tool holder is shown in a horizontal position because it is more convenient to represent it in this way. The front of the cross slide carries a tool block *L*, in which the two tools *M* and *N* are set in such a position that they will face the shoulder and the end of the hub, respectively.

The second operation on the work is done by a holder *O* of similar form to that just mentioned. The tools carried in it are finishing tools for the same surfaces as those previously machined. The rear of the cross slide is equipped with a block *P* carrying a

tool *Q*, which finish-faces the shoulder and cuts a recess for the thread. The tool *R* finish-faces the end of the hub.

The next tool used is a reamer *S* carried in a floating holder *T*. This reamer sizes the 1.500-in. hole and is piloted in order to preserve the alignment. The final operation on the work is done by means of a diehead of the opening type, shown at *U*. Care must be taken in using large dieheads for cutting threads to make sure that the capacity of the machine is sufficient to

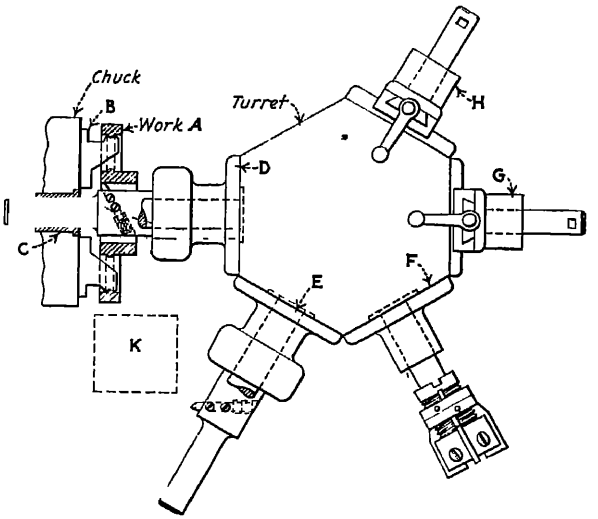


FIG. 170 —Turret layout for plain pulley.

permit the diehead *to swing over the back of the turret slide* when indexing.

There are several methods of making turret layouts. Some factories show a simple yet complete set-up, with all the tools in place on the turret. Others go a step further and show the turret set-up with tools on one sheet, while on another each operation is shown in detail with the tools in their respective positions. There is still another method in vogue, which shows all the tools on the turret and each operation in detail on the same sheet. In addition to this, all tool numbers and reference numbers to drawings on which tool details appear are given on the sheet, and each operation is specifically noted by means of reference letters on the various surfaces which are to be machined.

In selecting a method, the tool engineer should be governed partly by factory conditions and the procedure in the past. Judgment must be used in the matter and a suitable method selected and standardized in order to obtain uniformity. If tool layouts are blueprinted and made up in book form for factory reference, the sizes of sheets should be uniform and of such shape that they can be easily handled.

In Fig. 170 is shown a turret layout of a plain pulley with all the tools in position on the turret. Figs. 171 and 172 show the various operations in detail. Referring to Fig. 170, the work *A* is a plain pulley which is to be turned, bored and faced on both sides. It is held by the inside of the rim in a set of special

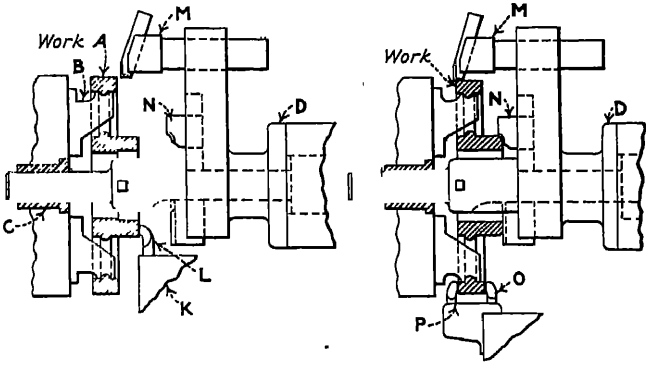


FIG. 171.—Start and completion of first operation on plain pulley

chuck jaws *B*, which are so made that the facing tools on the cross slide can pass by the edge of the flange without interference. The tool holder *D* contains a boring bar, corner tool and turning tool for the outside diameter, all being used for the roughing operation.

The holder *E* is a duplicate of *D*, except that it is used for finishing, and the corner tool is left out because one cut is sufficient to do the work. Holder *F* contains a reamer which is arranged so that it will float and follow the hole generated by the boring tools. Tools *G* and *H* are standard slide tools, which are used for rough- and finish-facing the back of the pulley hub. The cross slide in this machine has a turret toolpost *K*, in which are held the tools used to face the front of the hub and both sides of the flange.

The starting and completing of the first operation on the pulley is shown in Fig 171. The cross-slide tool *L* is first used for

facing off the end of the hub. After this cut has been started, the turret is brought up until the boring bar pilot enters the bushing and the boring tool commences to cut. Soon after this the turning tool *M* comes into operation. About this time the facing tool *L* has completed the work on the end of the hub; it is therefore withdrawn and the turret toolpost indexed to allow the two facing tools *O* and *P* to be used on the sides of the flange. Meanwhile the boring and turning tools continue to cut, eventu-

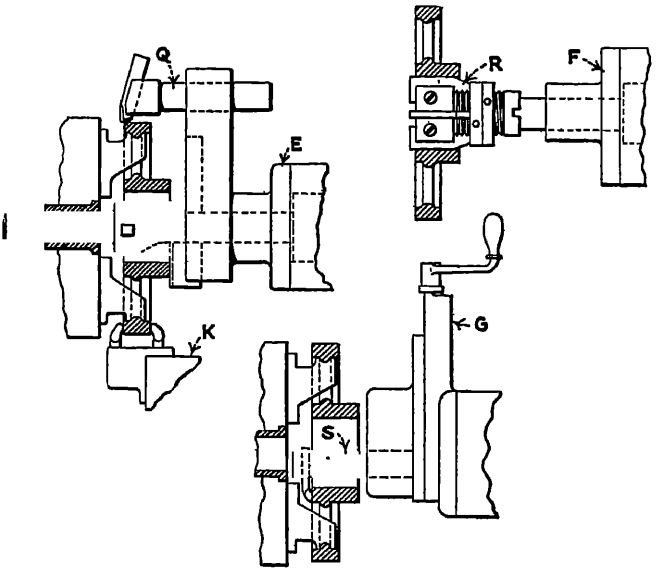


FIG. 172.—Remainder of operations on plain pulley.

ally completing their work, at which time the "knock-off" stops the turret slide. Hand feed is then used to round the corner of the hub with the tool *N*.

In Fig. 172 is shown the remainder of the operations in detail. The cross-slide tools continue to face the flange while the finish-boring bar and turning tool *Q* in the holder *E* on the second turret face are brought up and set to work. The knock-off on the cross slide stops the slide at the proper point and the facing tools remain in the position shown, or they can be run back out of the way if desired.

The hole is reamed with an adjustable reamer *R* in a holder of the floating type. On a cast-iron piece such as that shown, the

reamer is usually fed by hand in order to size the hole more rapidly. If a slow machine feed is used, there is always the possibility of enlarging the hole slightly, due to the scraping action on the edges of the blades. The production is faster if the reamer is fed by hand, and the work is more uniform.

The last two operations on the work are rough- and finish-facing the back of the hub. A bar *S* inserted in the slide-tool *G* is operated by hand in a vertical direction. The turret is brought

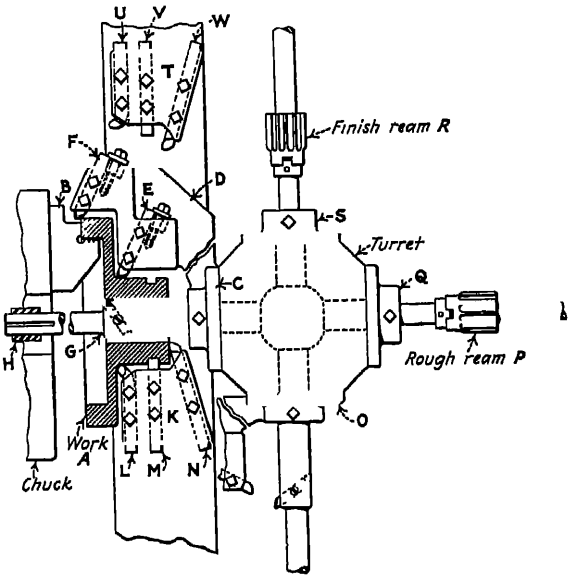


FIG. 173.—Turret layout for machine with four-sided turret.

against a stop to obtain the correct longitudinal position, and held in place during the operation.

Many turrets have six sides, but there are also those with five, four and three. The majority of the machines in common use have either six or four sides, although on certain kinds of work the others are often used. Some years ago a certain type of turret lathe was made with an eight-sided turret; but this type was not used very generally as its field was limited, due to the possibility of interferences of turret tools with others on the cross slide of the machine. The six-sided turret occasionally causes trouble in this regard, so that the tool engineer must keep his eyes open in order to make sure of the necessary clearances.

A four-sided turret allows more tool clearance and there is little chance of trouble being caused by a lack of room for the tools. Fig. 173 shows a layout for a piece of work *A* which is to be handled on a machine having a turret with four sides. The piece is held by the inside of the rim in a set of special jaws *B* in a three-jaw chuck, in which the bushing *H* is fixed to act as a guide for the boring bars and reamers. The holder *C* is fastened to the first turret face and has an extension bracket *D*, in which are carried the turning tools *E* and *F*. Fine adjustment is provided by means of the backing-up screws shown.

The tools in the holder are set vertically, although for convenience they are shown in a horizontal plane in the layout. A rough-boring bar *G* is held in the same holder and used for boring the hole in the hub. The front of the cross slide has a special tool block *K* in which are held the facing and grooving tools *L*, *M* and *N*. These latter are roughing tools used for making the first cut on the flange, facing the end of the hub and roughing out the groove $\frac{1}{32}$ in. under the finished size.

The tool holder *O* on the second turret face is exactly the same as that used on the first turret face, but it finishes the surfaces roughed off in the previous operation. While this tool is in use, the rear tool block *T* on the cross slide is brought up into position, so that the tools *U*, *V* and *W* perform the finished-facing and grooving operations. The third turret face carries a roughing reamer *P* which is supported in a floating holder *Q*. The fourth and last turret face has a holder *S*, which is also of the floating type and carries the finishing reamer *R*.

This use of two reamers, one for roughing and the other for finishing, is not common, yet it is used occasionally when very accurate work is required. In this layout of tools the attention of the designer is called to the operation of the turret turning tools and the cross-slide facing tools, as the lengths of the various cuts are so nearly the same that the turning and facing operations are completed at practically the same time with the equipment indicated.

In order to illustrate the application of one of the methods of making turret layouts, we give a complete layout in Figs. 174, 175 and 176 of a special equipment used in machining a bevel ring gear for the rear axle of an automobile. Fig. 174 shows the work *A*, which is a drop forging of alloy steel, held by the outside in a set of special chuck jaws *1*. These jaws are undercut, so as to grip

the work firmly and prevent it from being pulled out of the jaws during the cutting. The surfaces which are being machined are lettered, and all tools used are numbered and listed at the bottom of the layout sheet.

A brief description of each operation, together with a reference to the portions of the work on which the cuts are being taken, is

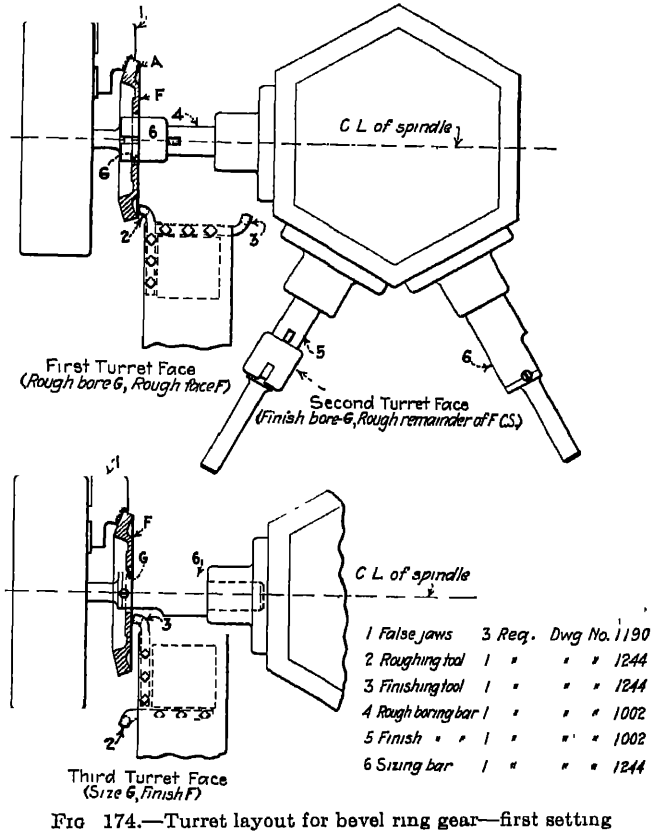


FIG 174.—Turret layout for bevel ring gear—first setting

given with each layout showing details of the set-up. For example, the first operation consists of rough-boring the hole *G* with a special boring bar *4*, and rough-facing the surface *F* with tool *2* in the turret toolpost of the cross slide. The remainder of the operations shown on this sheet are clearly specified and all tools used are listed with their drawing numbers at the bottom of the sheet, so that tool drawings can be easily found when wanted.

The title of the drawing and other information as to the work and the machine on which the tools are used is given in the lower right-hand corner of each drawing, in the usual manner.

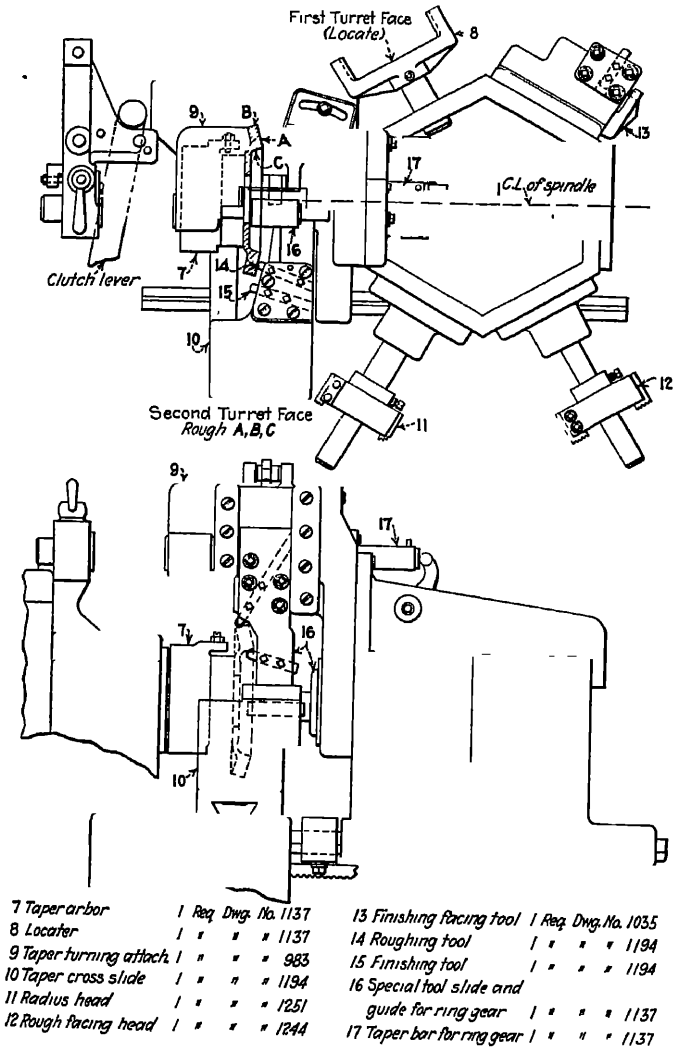
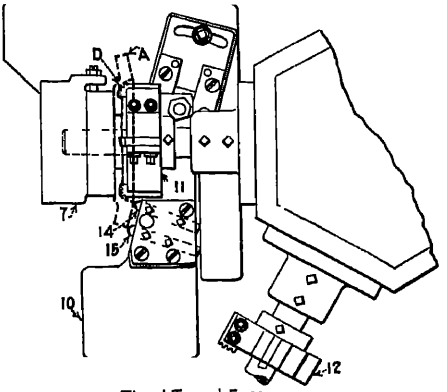
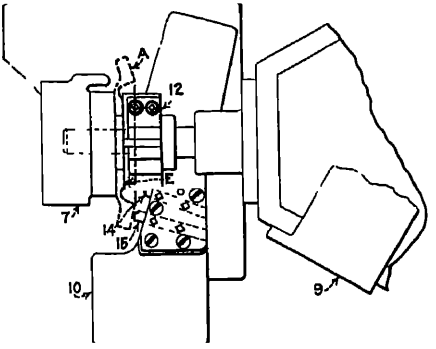


FIG. 175.—Turret layout for bevel ring gear—second setting.

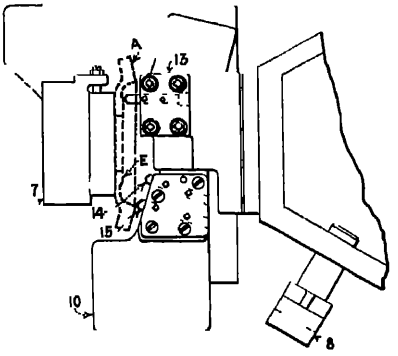
Between the first and second turret lathe settings, the bolt holes are drilled in the face F which has just been machined. This



Third Turret Face
(Rough remainder of A, Face D rough)



Fourth Turret Face
(Finish A, Rough E)



Sixth Turret Face
(Finish remainder of A, Finish face E)

FIG. 176.—Turret layout for bevel ring gear—detailed operations of second setting

provides a means of driving the work during the heavy cutting of the beveled faces. In order to make this layout clear, a description of the holding device is necessary and some mention of the other tools used in Fig. 175. The work is located on a large special arbor *7*, which is fitted to an adapter on the spindle in such a way that it can be trued up when necessary if it does not run perfectly true with the spindle. The arbor is provided with a pin which enters one of the bolt holes and acts as a driver. A taper plug in the center of the arbor acts upon three shoes which expand in the hole and grip the work and center it at the same time.

A locating device *8* is mounted on one of the turret faces and used when setting up the work on the arbor, in order to hold the piece up against the shoulder and preserve the correct location. In the first operation in this setting, a special taper turning attachment *9* (which was described in detail in a previous chapter) is used for turning the back angle and boring the inside angular surface of the gear blank shown at *B* and *C*. A special tool block is mounted on the slide for this work, and because of the excessive overhang a support *16* is provided, in order to give the necessary stability and prevent any vibration.

A special taper cross-slide *10* is used for rough- and finish-facing the face angle of the gear *A*, the two tools *14* and *15* being used for the work. These tools are set far enough apart so that the roughing tool has completely finished its work before the finishing tool starts. The tools *11*, *12* and *13* are used for roughing the inside surfaces of the blank. The combination of a special cross slide with a taper turning attachment on the turret increases the production greatly and gives very accurate work, as all the surfaces are machined by single-point tools controlled by accurately set taper forms.

The remainder of the operations are shown in detail in Fig. 176. The taper cross slide continues to work after the turret taper attachment has been withdrawn. The turret is indexed and the radius cutter head *11* is used to remove the stock from the curved portion of the blank *D*. The tools in this cutter head are arranged so that they do not interfere with the continued action of the taper cross slide The material which is being cut is tough and "wirey" so that the radius at the cutting point of the tools is nicked to break the chip and make the cutting action easier. The grooves in one tool overlap those in the other, so that the finished surface does not show any grooves.

The rough-facing head *12* is the next tool used for roughing the surface *E*. The toolbits are nicked the same as the radius tools to break the chip, and the tool positions are such that the cross slide continues to work on the facing of the angle without interference. The blank has now been completely roughed where necessary and finished on all important surfaces except the portion *E*, which has only been roughed.

To be sure of an absolutely true surface at *E*, the work should be faced with a single-point tool; but as the cross slide is set at an angle it cannot be used, and as the turret has no crossfeeding movement it is evident that it is not available. In order to overcome the difficulty, a special slide tool *13* is mounted on the turret so that a single-point tool takes the position shown ready for the facing cut on the surface *E*. This tool is brought up to its place just as the angular facing cut is completed by the cross slide. The feed of the latter is reversed and a block on the cross slide engages with a slot in the under side of the sliding member on the turret, thus causing the single-point tool to move across the surface to be faced and producing a true and accurate finish.

The entire equipment shown in these layouts is considerably out of the ordinary and it is not by any means cheap; yet all of the tools are so designed that they can be adapted to a number of different pieces of work, so that the cost distributed over the various parts is not excessive. Furthermore, the work produced is of great accuracy, which is an essential item in the manufacture of bevel gears and pinions. The production is very rapid, and there is little time wasted either in setting-up or in machining.

Another Method of Making Layout.—When it seems desirable to show a turret layout and details of the various operations on the same drawing, the arrangement must be carefully studied in order to avoid confusion. As these layouts are used in the factory, they should be as clear as possible so that the persons who use them will be able to understand the tooling methods readily. Fig. 177 shows a complete layout for a turret lathe operation on one-half of a rotor casing for a gyroscopic compass. This work required great accuracy and the tool equipment was designed with this point in mind, although a number of standard tool holders were used because the production required is not very high and only a few parts of any one kind are machined at one time.

The work is held by the outside in a set of special chuck jaws *3* in a standard three-jaw universal chuck. The casting is of an aluminum composition and somewhat fragile, so that the position of the jaws in their relation to the work was selected with care in order to avoid distortion. A universal turning and facing head *6* holding a boring bar *12* and various other tools designated by number, is used first on the work for roughing the surfaces *B*, *C*, *E*, *F*, *G* and *H*. The tool *7* in the cross-slide turret toolpost is fed outward and used in roughing off the surfaces *A* and *D*. The second operation is that of finishing *C*, *F*, *G* and *H* with another tool holder on the turret, and a final cut is taken across *A* and *D* with a tool *18* in the cross slide.

The third operation finishes *E* and sizes *F* and *H* using a special boring bar *22* and a forming tool *21* on the turret toolpost of the cross slide. In using the latter the cross slide is located against a longitudinal stop and the tool fed outward by hand until the indicating dial on the crossfeed screw shows that the correct diameter has been obtained. The operator would allow the tool to dwell here for a moment in order to obtain a smooth finish.

The fourth operation is that of reaming the hole *F* with the reamer *25*, which is held in a special floating holder in the body of the tool holder *27*. This tool holder carries a tool *26* used for roughing the groove *B*, which is very important as it fits a bead on the other side of the case. Attention is called to the fact that this tool is held vertically instead of horizontally in order to obtain as high a degree of accuracy as possible. The importance of this arrangement has been mentioned previously.

In the fifth operation a vertical slide tool holder *31* is furnished with two tools *30* and *32*, which are accurately set to preserve the accuracy of the distance from the face *A* to the surface *G*. The sixth operation is the final sizing of the groove *B* with tool *34* in holder *27*. This sizing is the last operation on the work, because it is of such importance that it is desirable to do it alone and thus make sure that no changes in relation can occur due to the possible shifting of the work.

The various examples of layouts given in this article cover a considerable variety of work, and the methods described are all in use in various factories. A decision as to the most suitable method for a given shop should be reached only after a discussion of the merits of each and a knowledge of conditions which affect the situation. Speaking generally, the writers favor the process

shown in Figs. 174, 175, 176, largely because the operations are shown so clearly, and the sheets are so proportioned that they can be photostated and bound up in a loose-leaf letter-size book for convenient reference.

CHAPTER XIV

VERTICAL LATHES, VERTICAL MACHINES AND BORING MILLS

POINTS OF IMPORTANCE IN DESIGN OF CHUCKS AND FACE-PLATES—SPECIAL FIXTURES FOR HOLDING IRREGULAR WORK —ADAPTABILITY OF VERTICAL MACHINES—USE OF FORGED TOOLS—SLIDING FIXTURES AND REAMERS

In previous chapters we have described methods of handling work on turret and engine lathes. These machines are used for work up to 16 or 18 in. in diameter, and occasionally for pieces of even larger size. For heavy work of large diameter, and even for some kinds of work of comparatively small diameter, the vertical turret lathe and vertical boring mill are more suitable. One of the principal reasons for this fact is the difficulty experienced in chucking large and heavy work on the horizontal type of machines.

It is unnecessary to discuss the relative merits of vertical and horizontal types of machines for boring, turning and facing, as the field of one overlaps that of the other to some extent, so that it becomes largely a matter of the selection of a machine most suited for a given piece of work. Speaking generally, the vertical turret lathe and vertical boring mill are suited to heavy work requiring the removal of considerable stock. Machines of this type are very powerful and adapted to heavy cutting with coarse feeds. The tools and fixtures for vertical boring mills bear a strong family resemblance to those used on turret lathes; they are, however, considerably heavier and capable of withstanding greater pressures.

There are several types of vertical boring machines, differing from each other in their general details of construction. One of these types is the vertical turret lathe, another the vertical boring mill, another the multiple-spindle semi-automatic chucking machine. The first of these approaches the horizontal machine most closely in its general features of construction The application of tools is also quite similar, although there are

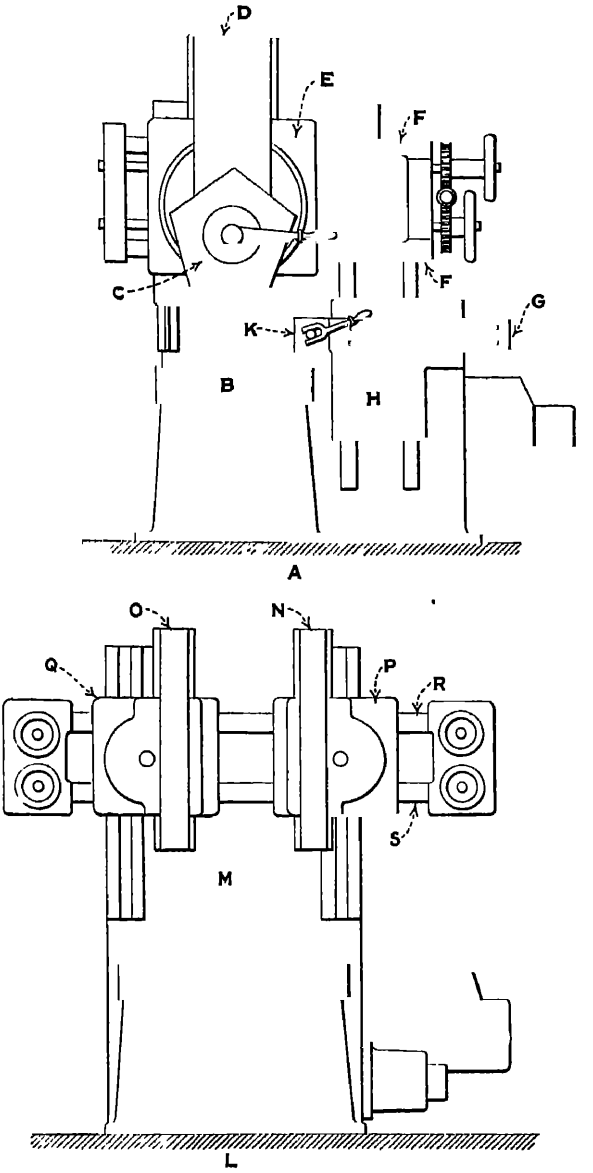


FIG 178 —Diagrams of vertical turret lathe and boring mill.

distinct points of difference. In order that the designer may understand the general details of construction of vertical turret lathes and boring mills, a diagram of each type is shown in Fig. 178. These diagrams are not intended to reveal details of the machines, but only to show general points in construction.

The diagram at *A* shows a vertical turret lathe having a heavy table *B* in which chuck jaws are mounted. The turret *C* has five sides and is located on a vertical slide *D*. The saddle *E* slides horizontally along the guides *F*, a positive stop being provided for determining the central position of the saddle. The turret slide is so mounted that it can be swiveled to an angle of 45 deg. on either side of the center line, thus adapting it for angular work. The sidehead *G* is of very heavy construction, and is located on a vertical slide *H*. A four-sided turret toolpost *K* is provided with slots for holding tools.

The speeds are obtained through a transmission gear case and clutches quite similar to the type used for automobiles. A wide range of feeds is obtainable through a gear box conveniently located. The necessary changes can be made rapidly, and suitable markings enable the operator to know just what feeds he is using. The slides have power rapid traverse in order to assist in setting for various positions. Diameter readings are obtained by means of graduated slides, micrometer dials and observation stops arranged so that they can be conveniently read by the operator. The machines are capable of the heaviest kind of cutting on steel and a very high degree of accuracy can be obtained. Machines of this type are made in capacities ranging from 24 to 54 in. in diameter.

The vertical boring mill at *L* is similar in general construction to the vertical turret lathe just described, except that there is no sidehead or turret. In some cases a special slide on this type of machine is furnished with a five- or six-sided turret, but this is not standard on all types of machines. The points of difference between the vertical turret lathe and vertical boring mill can be readily appreciated by a reference to the illustration. The table *M* is provided with chuck jaws and T-slots for holding fixtures when necessary. The toolslides *N* and *O* are held in saddles *P* and *Q*, which are adjustable along the horizontal guides *R* and *S*. Occasionally both heads are arranged so that they can be swiveled through an arc of about 45 deg. Standard tool holders with forged tools of suitable shape are located in a hole in the lower end

of each toolslide. A positive means of clamping and locating is provided. Rapid power transverse of toolslides and saddle is given, to avoid the necessity for long and tedious hand adjustments. A wide range of speeds and feeds is obtainable through a transmission case, clutch and gear box.

These two types of machines are the only ones for which we shall consider tooling methods. The multi-spindle semi-automatic chucking machine requires special study, and as this work is somewhat specialized we do not feel justified in going into the subject in detail. In general, the principles which we have mentioned and the methods described will apply to all varieties

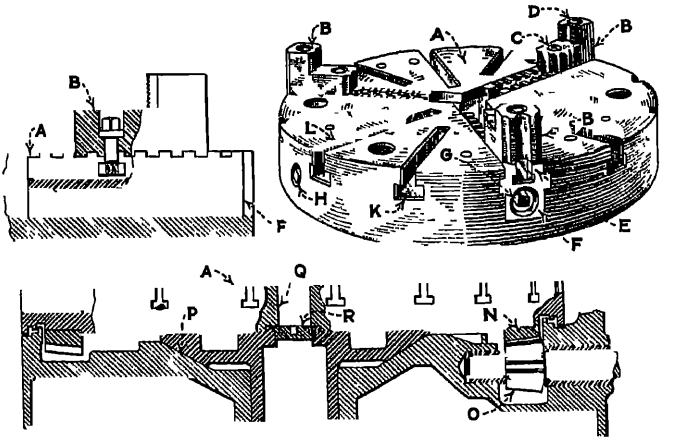


FIG. 179.—Boring mill table and chuck

of turning and boring machines, with modifications to suit the different types.

The method of holding work on boring mill tables is of interest, and while the chuck and jaws are similar to those used on a horizontal turret lathe, the application of fixtures to the table is somewhat different. Fig. 179 shows a perspective view of a boring mill table at *A*. This example has a three-jaw universal chuck built into the table. The jaws *B* are held down on sub-jaws *F* by means of bolts shown at *C* and *D*. The table itself is slotted in a number of places, as indicated at *K* and *L*, in order to facilitate clamping work or attaching fixtures. The center hole in the table is often used for obtaining the correct position of the fixture by using a locating plug in the hole.

The jaw arrangement is rather unusual, as each sub-jaw *F* is so constructed that its under side meshes with a scroll ring operated by a pinion. The movement of the jaws is obtained by using a socket wrench on the square head of the operating shaft *H*. Three of these shafts are located in the table so that they are easily accessible. Through the scroll ring the jaws are operated uniformly, but there is also an independent movement of each jaw obtainable by means of the screw *G*. This movement is convenient when chucking irregular work, as it allows the jaws to be set in different positions from the center, yet at the same time they can be operated with a universal movement.

The top of each jaw is grooved deeply across its face, so as to allow various settings of standard jaws. To keep the scroll ring covered and prevent chips from clogging the mechanism of the chuck, the sub-jaws are very long so that protection is assured at all times. The amount of movement of the sub-jaws is small, the top jaws being set in whatever position may be required for holding a given diameter of work. The detail illustrates the method of clamping the top jaws to the sub-jaws.

It must be remembered that the vertical turret lathe or boring mill has a table of large diameter, and it is therefore of great importance that it should be rigid and capable of withstanding a great deal of pressure during the cutting action. The sectional view through the spindle shows the table *A*, on the under side of which is a large bevel ring gear *N* driven by a pinion *O*. The table is attached to a spindle having a conical bearing seat *P*, which not only stabilizes the table but provides an ideal bearing surface. The hole *Q* in the center of the table is useful in locating fixtures or bushings. A filler plug *R* is placed as shown, in order to prevent chips and dirt from working down into the moving parts of the machine.

Fixtures used on vertical boring mills are for the most part simple in design, although exceptional cases may require a fixture more or less elaborate, according to the nature of the work. Such matters as the production required and the number of pieces which are machined in each lot have an effect on the design of fixtures. A great deal of work which is handled on boring mills is put through the factory in comparatively small lots, say twenty-five or fifty pieces at a time. When fixtures are required for work of this kind, it is necessary to make them so that they will

withstand rough handling and a considerable amount of wear on the various finished surfaces.

General matters connected with the design are much the same as those which have been previously mentioned on the subject of turret lathe fixtures. The only difference is in the size of the parts, which naturally require heavier fixtures and those capable of withstanding more severe usage. The following points must be considered in the design:

(1) The location of the work is of primary importance, whether it is the first setting of a piece of rough work or another setting in which the piece must be located from a previously finished surface. Points of location and surfaces on which the work rests should be made in such a way that they can either be trued up readily to preserve the accuracy or replaced by other units when worn.

(2) The rigidity and driving power of fixtures used for this kind of work is of supreme importance, as the cuts which are taken are heavy and there must be no vibration if first-class work is to be obtained. Even when work is held in chuck jaws, the shape of the work and the amount of material which is to be removed may make it necessary to provide additional means of holding and driving, in order to withstand the excessive pressure resulting from the cut. There is an old story told of a manufacturer of vertical boring mills; when asked how many machines one man could run he replied that "It takes two men to run one machine, one man to operate the machine and the other to carry away the chips." While we must admit that this statement is somewhat exaggerated, it illustrates the point and indicates the tremendous power and production possibilities of these machines.

(3) Economy in the design of fixtures for vertical turret lathes should be carefully studied, as the fixtures are often so large that the cost of patterns and cast iron alone may be excessive, unless considerable thought is given to the design. Another point in this connection is that the large size of the fixtures makes them somewhat awkward to machine, and it may be better to make them in several units, rather than to use a single casting of large size which would be difficult to machine. The methods of clamping do not generally require much of a special nature, but the necessity for holding the work rigidly makes it obligatory to use clamps to which sufficient pressure can be applied.

(4) Convenience and the accessibility of various movable parts on the fixture are quite important, and should be studied with

care when designing. Locating points should, if possible, be arranged so that they can be seen, even if it is necessary to core openings in the side of the fixture to allow the operator to look through and see where he is placing the work. The method of setting up a piece in the fixture should be such that it will be as convenient for the operator as possible. Certain kinds of irregular work may require a fixture having a latch which can be swung to one side when placing the work in position. When anything of this kind is necessary, the direction in which the latch swings should be such that the accidental starting of the machine will not cause the swinging member to come in contact with the sidehead or some other portion of the machine and cause breakage. The pivot should be so placed as to avoid any trouble of this sort.

(5) The removal of chips from fixtures often causes trouble, unless proper provision is made so that they can be readily swept out. A pot fixture, for example, may be excellent for holding the work; but if it is so constructed that it will soon fill up with chips, it will cause much loss of time in manufacturing. Cored openings can usually be provided so that chips will fall out by themselves. The experienced designer takes these points into consideration when making up a tool, no matter whether it is for a jig, cutter or fixture.

(6) The accuracy of the finished product may often effect the design of the fixture; hence, the tool engineer must consider this in the early stages of the design. For important surfaces which are to be machined in accurate relation to each other, the tool equipment must be designed with this point in mind. In the location of the work, also, the matter must be considered and proper methods of clamping and locating used.

Holding Work in Chuck Jaws.—A great deal of the work done on the machines of the types just mentioned is held by means of standard or special chuck jaws. We have previously shown a number of applications of chuck jaws to turret lathe work, and many of the points in design mentioned there are equally important for jaws used in holding work on boring mills. One point, however, which is quite different is the fact that the work is held in a horizontal plane, so that it is only necessary to lay it down in the chuck jaws in the proper position, its own weight keeping it in place while the jaws are being tightened.

There are exceptional cases when work is of such shape that it requires a special chucking device on the turret, but these cases

are rare and can usually be solved by a designer of average intelligence. Standard chuck jaws can often be used for holding work, unless it is of peculiar shape or would not permit the tool to pass over the surface to be machined if standard jaws were used.

In Fig. 180 are shown a number of examples of standard and

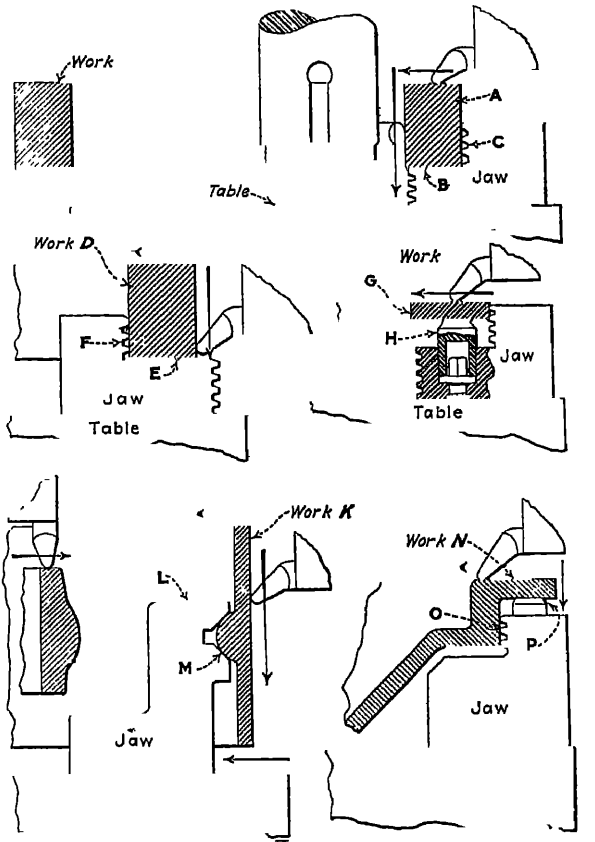


FIG 180 —Methods of holding work in chuck jaws

special chuck jaws in their application to various pieces of work In the example *A* the work rests on the surface *B* of a standard jaw, and is held by the outside as shown at *C*. Since this piece of work is to be bored and faced, as indicated by the arrows, it is clear that these jaws can be used for holding so that nothing special will be required.

In the example *D* the work rests on a standard jaw at *E*, being gripped by the inside as shown at *F*. The work which is to be done is facing the upper surface and turning the outside diameter, as indicated by the arrows. If set up in the manner shown, the outside turning tools could not be used without running into the jaws. It is not by any means necessary, however, to provide special jaws, as raising blocks can be placed under the rim of the work, thus providing clearance between the jaw and the work so that the tools can pass by. Another method of holding a piece of work in order to allow clearance for the tool is shown at *G*. Hardened buttons *H* are placed in the bolt holes of the jaws, and the work rests on these buttons.

The work shown at *K* is a large pulley which is machined on the outside, the two rims, the hub and the hole. In order to hold the rim so that these surfaces can be finished in one setting, a special form of jaw *L* is used. This jaw is cut out in V-form, as shown at *M*, so that it grips the inside of the flange and at the same time locates it in a vertical direction. The example shown at *N* also requires the use of special chuck jaws on account of the shape of the work. The jaw is made so that it grips the piece at the point *O*, and the flange rests on a hardened stud *P* on top of the jaw.

It must be remembered that the chucks on these machines are very powerful, and that, therefore, care must be used in gripping the work so that it is not distorted and thrown out of shape by the pressure of the jaws. Special methods may be necessary for thin work, in order to prevent trouble being caused by distortion. Other points in connection with the design of chuck jaws have been fully treated in previous chapters. Cases which require special treatment can usually be handled by an application of principles which have been mentioned.

It is very necessary to make fixtures for vertical turret lathes and vertical boring mills of a substantial nature, so that they will withstand the heavy cutting action. Not only must the fixtures be made strongly, but the method of holding the work must be such that the latter will not turn or change its position when heavy cutting is necessary. Certain kinds of work are of such a nature that they cannot be readily held in chuck jaws, and when such a part is encountered a fixture must be designed expressly for it. An example of this kind is shown in Fig. 181, in which the work *A* is a large cast-iron drum which is to be machined on the top, outside diameter and the flange. On account of the

shape of the work it cannot be held easily in chuck jaws, as these would need to be made very high in order to grip the piece securely. The fixture *B* is substantially made of cast iron and located on a plug *C* which fits the center hole in the boring mill table. The outside diameter of the drum is 19 in. when finished.

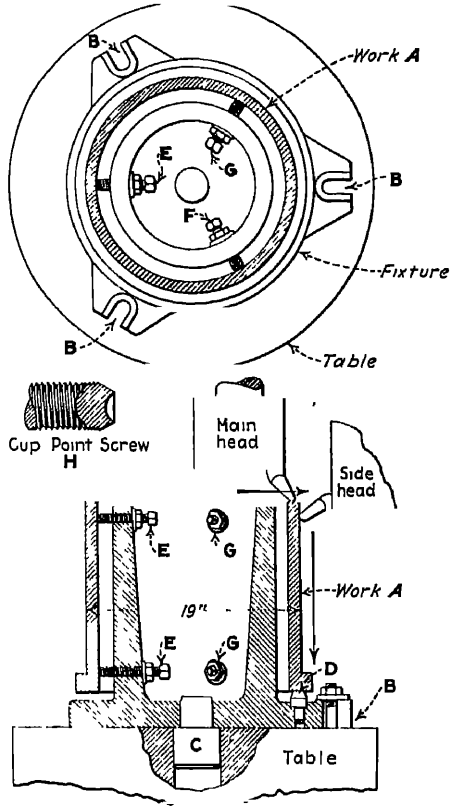


Fig 181.—Vertical turret lathe fixture for drum

The drum slips over the central portion of the fixture and rests on three hardened plugs *D*, spaced equidistantly under the flange.

A central location for the work is obtained by the use of setscrews *E* and *F* which are fixed in position. They are not disturbed when setting up the work on the fixture; but the setscrews *G* are easily accessible, and they are tightened by the operator with a wrench. It will be seen that the principle

used here is similar to others which have been described in connection with fixtures for horizontal turret lathes.

A point of importance is the shape of the setscrews used. The cone-point type is unsuited to work of this kind, as it is very difficult to set up this type of screw with sufficient pressure so that it will withstand the vibrations produced by the heavy cutting action. A cup-point screw like that shown in detail at *H* will give much better results, as considerably more than a point contact is obtained from this variety. On short cuts which do not require the removal of a great deal of stock, a cone-point screw may answer the purpose, but for general use a cup point is much superior as its contact with the work is so much greater.

Fixtures used for vertical boring mills are frequently very simple. Oftentimes some of the work required in finishing the fixtures can be done on the boring mill table, which is of course an advantage, as it is then certain that the fixture will run perfectly true with the table. Patterns used for large fixtures are generally simple and they are not finished carefully in the majority of cases. In order to prevent cracks and ruptures of the castings, all fillets should be made large.

Many cases are found in which it is necessary to hold a piece of work by an inside cored surface, in order that the piece may be finished true and concentric with the inside. The last example showed a simple method for holding work of this nature, but the shape of the piece itself made it possible to use a type of fixture which cannot always be adapted to inside holding. Fig. 182 shows an electrical unit *A*, the inside surface of which *B* is cored out, yet it is not possible for the operator to use a wrench to tighten setscrews as in the preceding instance. A simplified form of expanding pin chuck was therefore designed for this particular casting.

The body *C* is located on a plug *D* in the center hole of the boring mill table. Six pins *E* are spaced in suitable positions to give stability to the work and grip it from the inside. The pins in each tier are placed 120 deg. apart and their inner ends come in contact with angular surfaces *F* and *G* on the two cams *H* and *K*. The latter cam is threaded to receive the end of the operating bolt *L*. A coil spring *M* is placed between the two cams. A socket wrench used on the end of the bolt *N* operates the mechanism, thus moving the pins outward as much as is necessary to hold the work firmly. When the operating screw is loosened, the

springs in the pin sockets release the pins, thus allowing the work to be removed.

A principle of a similar kind can be used on work where it is not possible to place a wrench on top of the fixture as in this case. Other means for operating the cams must be devised. Occasionally this is done by means of bevel gears and a socket wrench

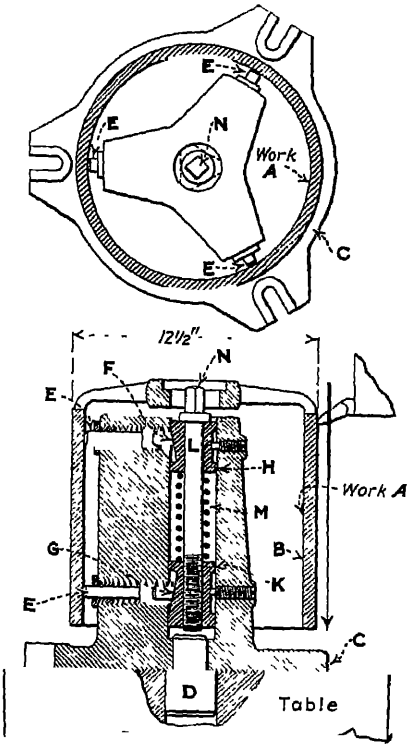


FIG. 182.—Pin chuck for electrical unit.

with a long handle extending beyond the edge of the table. Several methods are possible and the nature of the work governs the type of device found most useful.

When work has been machined partially in a previous setting, any other operations on the work may require it to be set up from the previously machined surfaces. As work which is handled on boring mills is usually of rather large size, the fixtures used are often of a somewhat different nature than those which would be utilized for smaller work on a horizontal turret lathe.

Locating rings or plugs can often be used when they are of small diameter; but when of large size the amount of surface which would be in contact with the work prohibits their use.

A great deal of trouble might be experienced in placing a piece of work on a large locating ring of, say, 15- or 18-in. diameter. In order to avoid this trouble, three or four blocks can be screwed and doweled to the fixture in the proper positions, like those shown in Fig. 183 at *A*, *B* and *C*. If these blocks are fastened

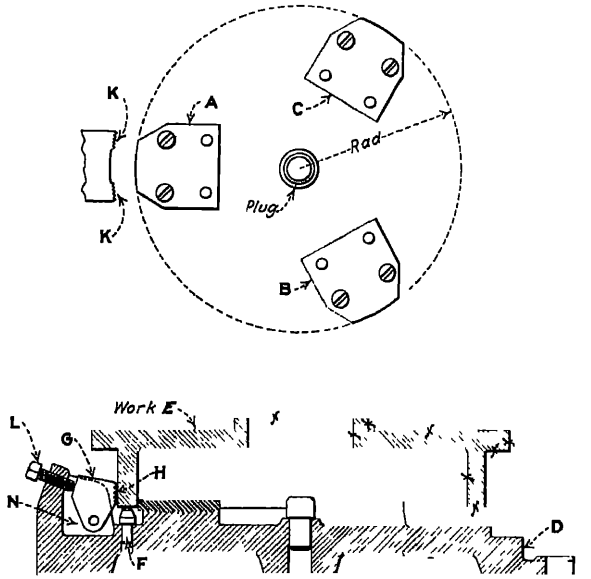


FIG. 183.—Second-operation fixture for vertical turret lathe

securely to the baseplate *D* which is located on the table, the outside of the blocks can be easily turned to the correct diameter while on the machine. Measurements can be readily made across the central plugs. There may be cases when these locating blocks need to be hardened, but often the production is not high enough to require anything of this kind.

The work shown at *E* locates by the inside finished surface on these blocks and rests on three studs *F*, which give the work the correct vertical position. The method of driving is by means of three dogs set opposite to the locating blocks, as shown at *G*. The surface *H* which comes in contact with the work is made as shown at *K*, and it is serrated much like a chuck jaw, so that it

will grip and hold the work firmly when pressure is exerted by means of the screw *L*. This example gives a very good illustration of a simple fixture of a type often useful for boring mill work.

In Fig. 184 is shown another example of a fixture used for second-operation work when the portion from which the loca-

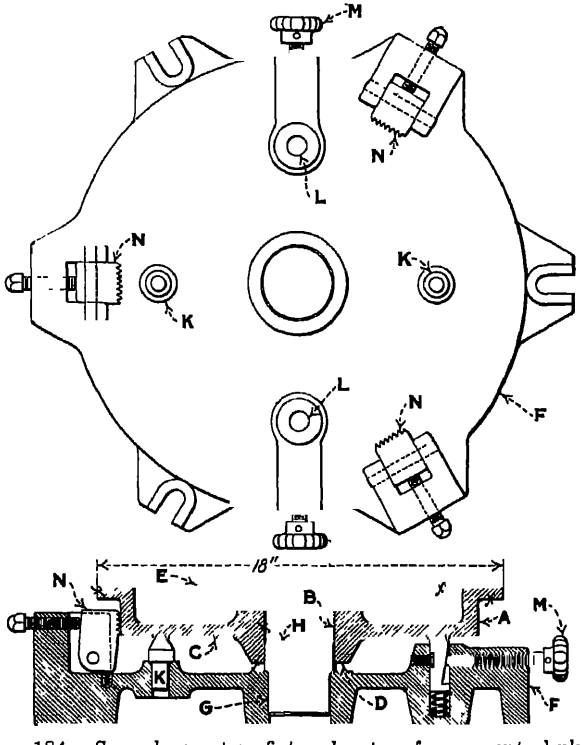


FIG 184 —Second-operation fixture locating from a central plug

tion is to be obtained is of comparatively small diameter. The piece shown at *A* has been previously machined in the hole *B* and on the undersurface *C* and *D*. The work to be performed in this operation is the facing, turning and undercutting of the flange *E*, the piece being located from the previously finished surfaces mentioned. The fixture base *F* is of cast iron and has a central locating plug *G* which fits the hole in the table. The upper part of this plug is enlarged at *H* and made to a diameter corresponding to that of the hole *B*. The work slips over the

plug and rests on two fixed studs K, which are located opposite to each other. Midway between them are spring jacks L of a type which has been described previously. The spring jacks are clamped in place by thumbscrews M. The method of driving the work is by means of swinging clamps N of somewhat similar design to those used on the preceding fixture.

There is, of course, one point which does not need to be con-

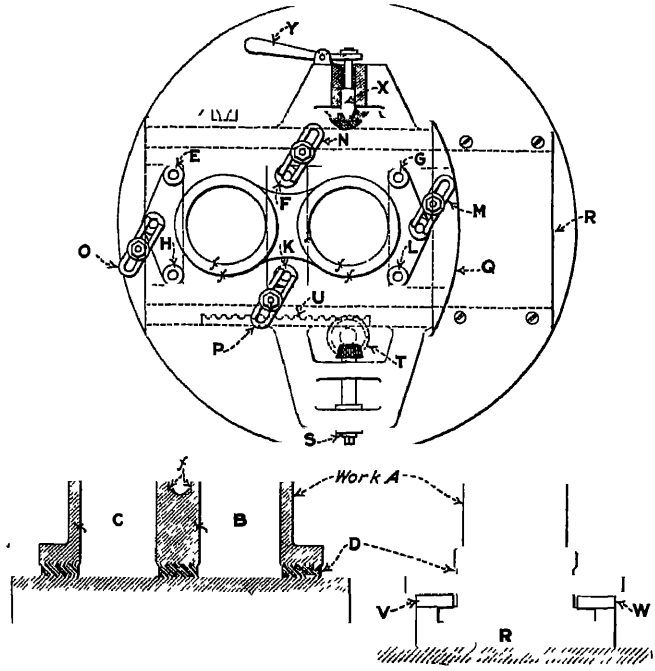


FIG. 185.—Sliding index fixture.

sidered when work is held on a boring mill table. This point is the matter of holding the work from falling off. Naturally as the work is laid down on the table, its own weight will hold it in place. This fact makes the design of fixtures for boring mills considerably simpler than for horizontal turret lathes. When making indexing fixtures or those which require the turning or boring of eccentric surfaces, a horizontal turret lathe requires fixtures which are carefully balanced; but with a vertical boring mill it is unnecessary to be so particular in this regard. The table is very heavy, and if the weight is more on one side

than on the other it does not make a great amount of difference. If it were found necessary to use a fixture on a boring mill which was very much heavier on one side than on another and to use this fixture continuously over a long period, it might be advisable to counter-balance it so that it would not cause inaccuracies on account of its eccentricity.

In Fig. 185 is shown a piece of work *A* having two holes *B* and *C* which are to be bored parallel to each other and some distance apart. A piece of work like this can often be handled on an upright double-head boring machine of a type in which the spindles revolve. This arrangement would allow both holes to be bored at one time, and the production obtained would undoubtedly be somewhat greater than by the method which we show. The work has been finished along the surface *D* and the six bolt holes *E*, *F*, *G*, *H*, *K* and *L* have been drilled The two holes *E* and *L* have likewise been reamed, and they are used to locate the work for this operation.

The method of clamping is by means of straps at *M*, *N*, *O* and *P*. The work rests on suitable pads with spaces between them, so that the chips will not accumulate. The sliding member *Q* is fitted to the base *R* so that it can be moved horizontally. Due to the weight of the slide the application of considerable power is necessary to move it, but this is obtained through a shaft *S* operating a pair of bevel gears and a pinion *T* which meshes with a rack *U* cut along the side of the sliding member. Heavy straps *V* and *W* are used to hold the slide down and an index pin *X* operated by a lever *Y* gives the correct location for boring the two holes.

Care must be taken when making fixtures of this kind to relieve the bearing surface of the slide so that there will not be too great an amount of surface in contact, as this would cause friction in indexing from one position to the other. If the amount of indexing necessary is small, other means can be provided which would do away with the necessity of the rack and pinion. Even this mechanism could be simplified considerably by using a plain rack and pinion with a ratchet handle, but the latter method would take considerable more time to operate than the device shown.

We have not previously taken up the use of forged tools to any extent, but in vertical boring mill work they are used a great deal, and standards have been developed for different

varieties which make it possible to handle a large amount of turning, facing and boring by the use of standard tools. A great many of the forged tools used are so designed that they will cut in more than one direction equally well In order to illustrate their possibilities, a diagram is shown in Fig 186 which will give a very good idea of the utility of the tools.

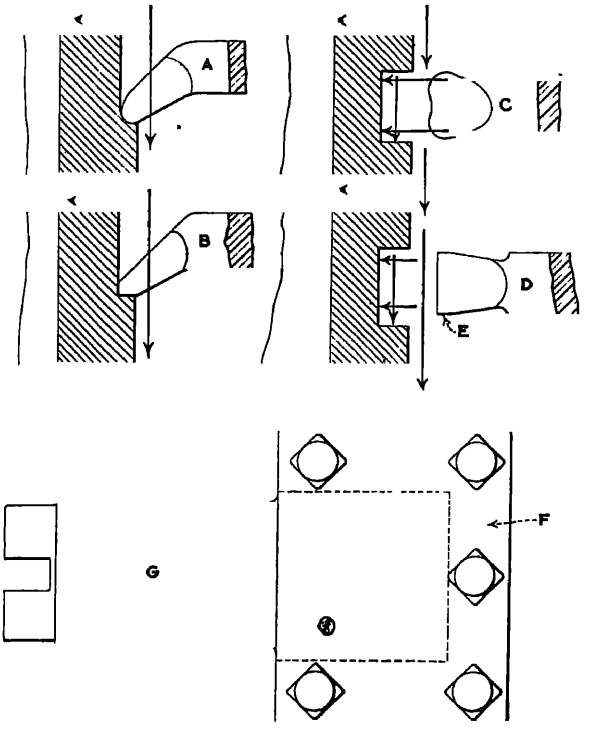


FIG 186.—Tools and toolholder for vertical turret lathe

For example, the tool *A* is used for rough-turning and facing as indicated by the two arrows shown. The tool *B* is used for finish-turning and facing and can be used in both directions as indicated by the arrows. These tools are made both right-hand and left-hand, and they can be used in either the turret tool holder or the sidehead.

The tool *C* can be used for rough-turning, rough-facing and roughing out a pocket or groove. This tool has a double lip and will cut in any of the directions shown by the arrows. It is not used for finishing and it does not produce an exceptionally

good surface, but it will remove stock rapidly and the cutting action is good. The tool *D* is used for finishing cuts or for grooving and it may be ground with a slight land at the corners as shown at *E* so that it will do a very good facing job. It can be operated in all of the directions indicated by the arrows.

These are the principal tools used in turning and facing and their simplicity is apparent, yet they are adaptable to a great variety of conditions. For the side-head the tools are held directly in the turret toolpost, but when used in the turret a toolholder like that shown at *F* is employed. This holder is a heavy forging fitting the turret hole and slotted so that tools can be placed in it in several different positions. It is sometimes made with the stem *G* considerably longer to take care of special lengths.

Boring and Reaming Bars.—A special type of boring and reaming bar has been developed for use in vertical boring mills. It is a multicutting bar and its construction makes it well worthy of careful consideration. Fig. 187 illustrates a number of applications of the bar to different uses and shows clearly its general features of construction. It must be remembered that boring tools and reamers used on a vertical boring mill are normally held when in use, in a vertical position, and that this position permits a type of construction to be used which would not prove satisfactory on a horizontal type of machine.

The diagram at *A* shows two views of the bar *B*, which is slotted at *C* and *D* to receive cutters of different kinds. The slot *E* is used for the reamer blade and is at right-angles to the boring tool slot which it intersects. A special setscrew *F* is used as a backing-up screw for the various boring tools and a hardened plug *G* is flatted on one side to back up the reamer blade when it is used.

The illustration at *H* shows a chamfering tool *K* in position in the bar The end of the tool *L* strikes against the head of the screw *F*, which gives it the proper location. The tools are ground so that they fit the slot accurately, yet they are free enough so that they can be removed by hand without difficulty. The pressure of the cut keeps them in position. In boring a piece of work, after the turret position has been determined there is no change made in it while chamfering, rough-boring, finish-boring or reaming The tools are ground to different lengths, so that various diameters can be produced according to the particular tool which is used

The application of a boring tool is shown at *M*, and another type *N* illustrates the method of cutting a recess or a shoulder when it is necessary to face the bottom of the hole. The cutter shown at *O* is used for chasing a thread on the inside of a piece of work. All of these tools are ground to pre-determined lengths in

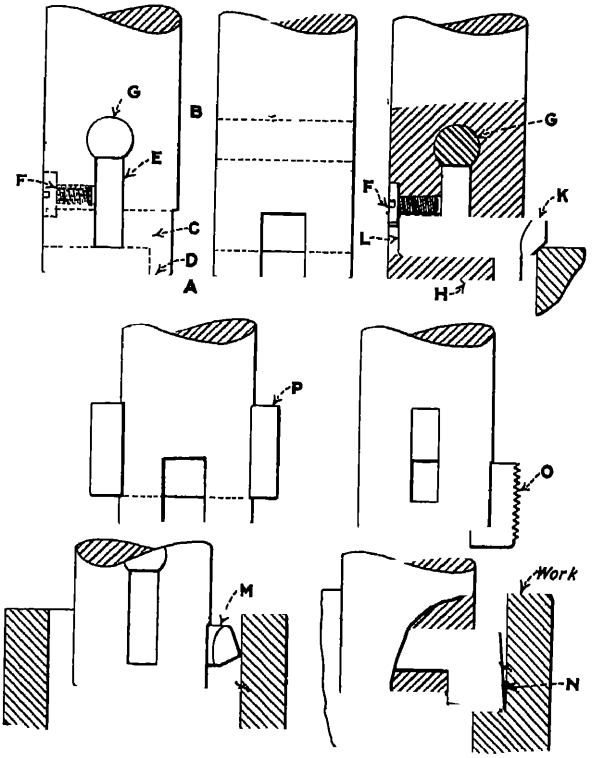


FIG. 187.—Type of boring bar used on vertical turret lathe.

special fixtures and the amount of finish allowance between cutters is pre-determined. The reamer blade *P* does not float in the ordinary way, but the blade itself fits the slot loosely, so that it centers itself and naturally follows the correctly generated hole. Special types of tools can be used in this bar when found necessary.

CHAPTER XV

TAPERED AND CURVED SURFACES

TAPER BORING TURNING AND FACING—MACHINING SPHERICAL AND FORMED SURFACES—METHODS OF LAYING OUT AND DEVELOPING THE DESIGN OF THE TOOLS

We have discussed the attachments used on a horizontal turret lathe for various pieces of work which require the generation of tapers. On the vertical turret lathe and vertical boring mill provision is made in the construction to handle a certain amount of this work without the use of special attachments. We have mentioned the fact that the head is arranged so that it can be swiveled to an angle of 45 deg. on each side of the center line. This makes it possible to set the head over so that different angles can be bored or turned without great difficulty.

Generating Inside Tapers.—In Fig. 188 is shown a piece of work *A* held in chuck jaws *B* on the outside diameter. The work which is to be performed is indicated by the various arrows. The angle of the taper is 15 deg. and the head is therefore set over to this angle. The tool holders *C* and *D* carry, respectively, the roughing tool *E* and the finishing tool *F*. After the correct angle has been obtained, it is only necessary to start the down feed to the turret slide, and the tools will generate a correct taper on the inside of the work. While this operation is taking place, the tool *G* in the sidehead is used to rough off the surfaces *H*, *K* and *L*, the feeds used being in the directions indicated by arrows. The tool *M* is used for finishing the same surfaces. The simplicity of this arrangement will be readily seen, and the possibility of adapting it to a variety of conditions is apparent.

The work *A* shown in Fig. 189 requires the turning of the outside taper surface. This work could be done by means of the turret slide, which could be set to the proper angle; but if this were to be done a re-setting would be necessary when boring the hole *B*. In order to avoid this contingency the sidehead tool *C* is used for turning, the correct angle of the taper being determined by a special block *D* held in the holder *E* in the turret. The latter

is locked in position during the operation, and the sidehead movement is controlled by the contact of the roll F against the forming plate.

In order to hold the roll against the plate, the binder on the sidehead is set up tightly enough, so that the head can be forced outward as the down feed of it continues. Various applications can be made of this same principle in handling tapers on a vertical

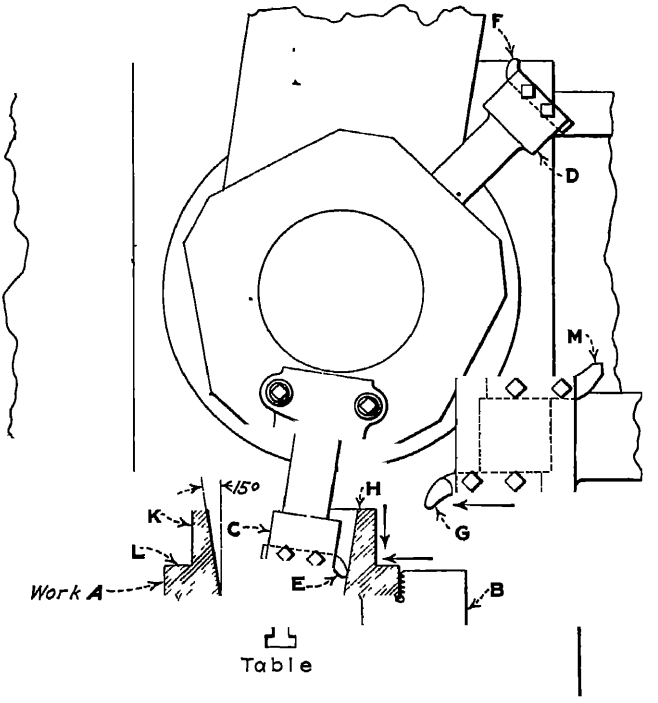


FIG. 188 —Generating a taper inside surface.

turret lathe. There may be occasional instances when it is not desirable to tie up both turret and sidehead, as is necessary when using this method. Other means will be described later to avoid such a condition.

Taper Facing.—When a taper surface is to be machined in a horizontal plane, a reversal of the principle just described can sometimes be used. Fig. 190 shows a piece of work A which has previously been machined at B and C. It is located on the fixture D, the central position of which is assured by means of the

plug E which enters the hole in the table. The work locates at B and is clamped down by means of straps F. A taper block G of special form is held in the sidehead turret H, the latter being firmly locked so that it does not move during the operation. The tool K is held in the holder L, at one side of which is a roll holder

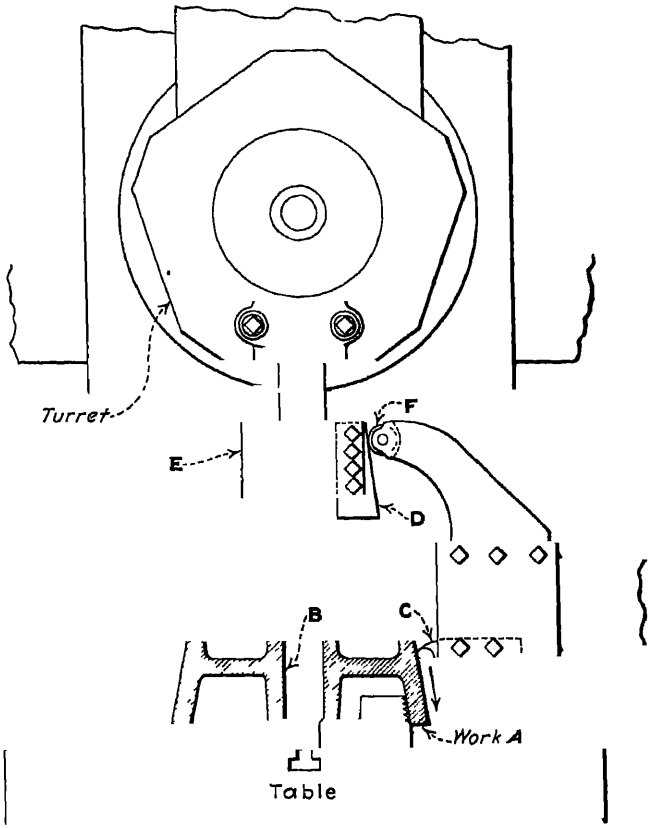


FIG. 189.—Attachment for turning an outside taper.

M carrying a roll N which travels along the angle of the taper block, thus generating the proper angle. The operator is obliged to keep pressure in a downward direction on the turret slide when using this method, in order to keep the tool in continual contact with the form. The simplicity of this device and the ease with which it can be set up are recommendations in its favor.

All of the methods illustrated here for turning tapers, with the exception of the first, have necessitated tying up the sidehead and turret. This is not always desirable, as it decreases the production time. If both sidehead and turret can be used at the same time, the production is naturally increased to a considerable extent. Therefore a taper attachment can often be

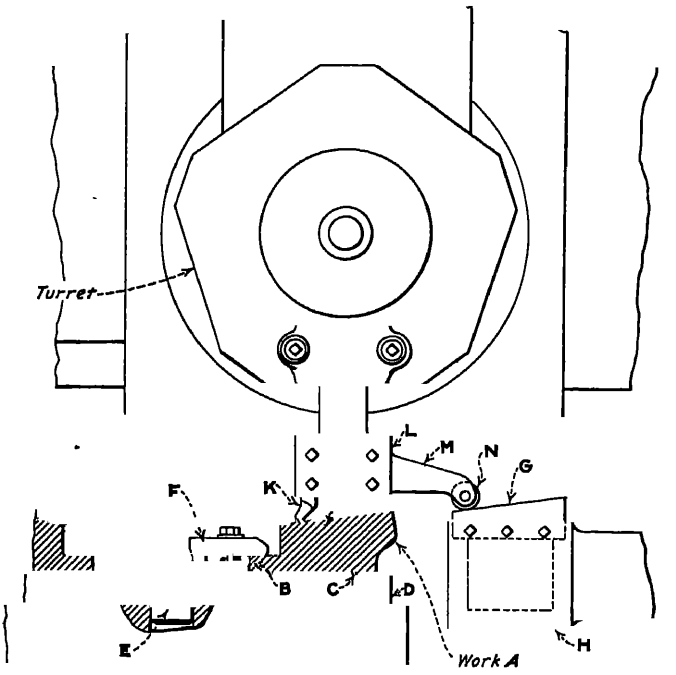


FIG. 190.—Facing an angular surface by means of a simple attachment.

applied to advantage if there is sufficient work to warrant its use.

An example of this sort is shown in Fig. 191, in which the work *A* is held by the inside in special jaws *B*. It is desired to turn the taper *C* and face the surfaces *D* and *E* in the same setting. The plate *F* is supported at each end by rods *G* and *H*, which are adjustably mounted in brackets *K* and *L* attached to the machine body. The sidehead *M* is fitted with a roller *N* which engages with an angular slot *O* in the form plate. The roughing tool *P* is used in the sidehead of the machine and a finishing tool *Q* can be swung into place when needed. The

holder R contains a tool S which is used for facing the surfaces D and E.

While this facing operation is in process the down feed of the sidehead is started and the roller N travels along the angular slot, thus generating the outside taper. For the finishing operation the sidehead turret is indexed and the tool Q completes the work. A principle like this can be used in finishing various

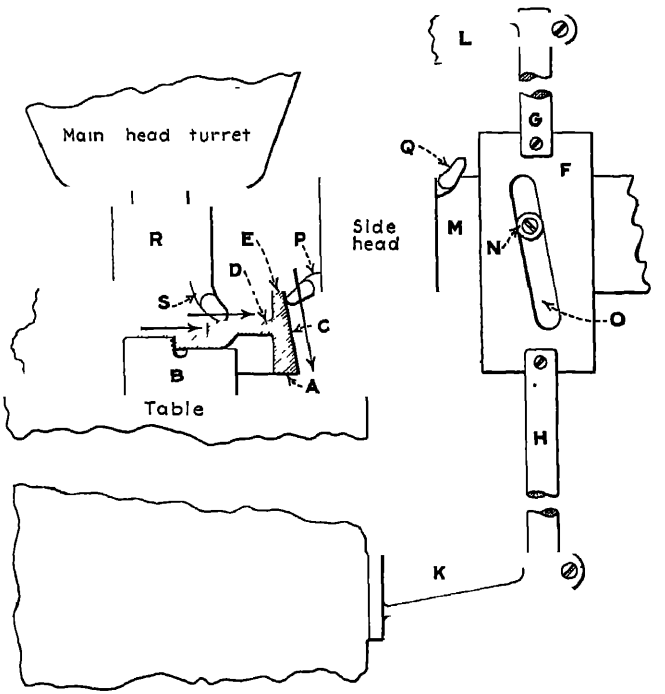


FIG. 191.—Taper turning with sidehead

forms, the plate F being made special to suit the requirements This attachment is simple and the plates are easy to make, so that various angles can be machined without great trouble.

When it becomes necessary to face a tapered surface on a vertical boring mill the problem is slightly more difficult, yet even here a few simple parts can be made and applied to the machine so that good results can be obtained. In the example shown in Fig. 192 the work A is similar to that indicated in Fig. 190, but it is of much larger diameter and is handled on a different type of machine having no sidehead. The work is located on a

fixture and clamped by means of straps B in the same manner as that previously described. The taper surface C is to be generated and the tool D held in a standard holder E is used for the purpose.

Two brackets at F and G are fitted to the cross-rail of the machine and carry a flat bar H, on the back of which a taper plate K is fastened. The toolslide carries a roll L which comes

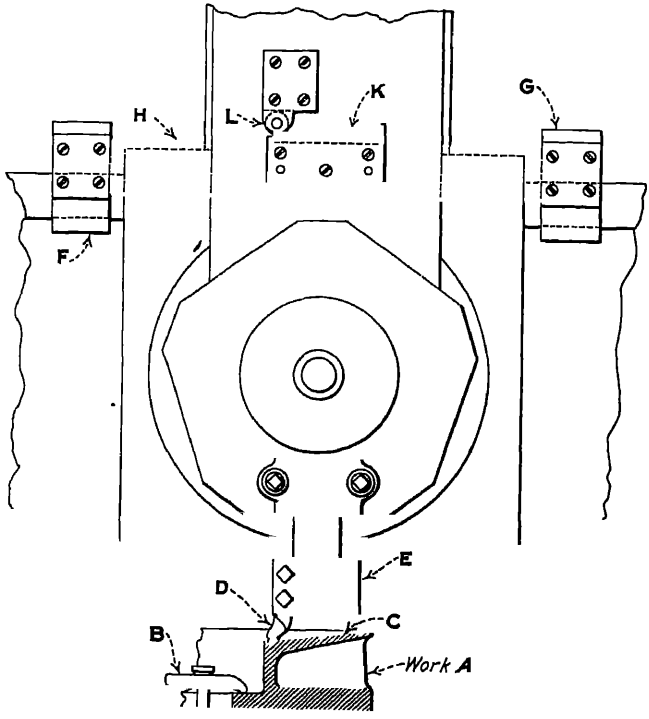


FIG. 192.—Generating a taper surface by using a form plate carried on the rail.

in contact with the taper plate, thus making it possible to control the angle of the taper. The pressure is kept on the toolslide in a downward direction, so as to keep the roll in contact with the form plate while the longitudinal or crossfeed of the toolslide is in use. It must be remembered when designing an attachment of this kind that the parts must all be made sufficiently strong to withstand the pressure to which they are subjected.

Tapers of various kinds may occasionally require machining, and the method most suitable is dependent largely upon the

number of pieces which are to be machined, the accuracy required and the other operations which are to be performed in the same setting It is advisable to select a method which will take these points into consideration, and if production will be greatly increased by the use of a special attachment, it can be designed according to the requirements. Many devices for taper turning

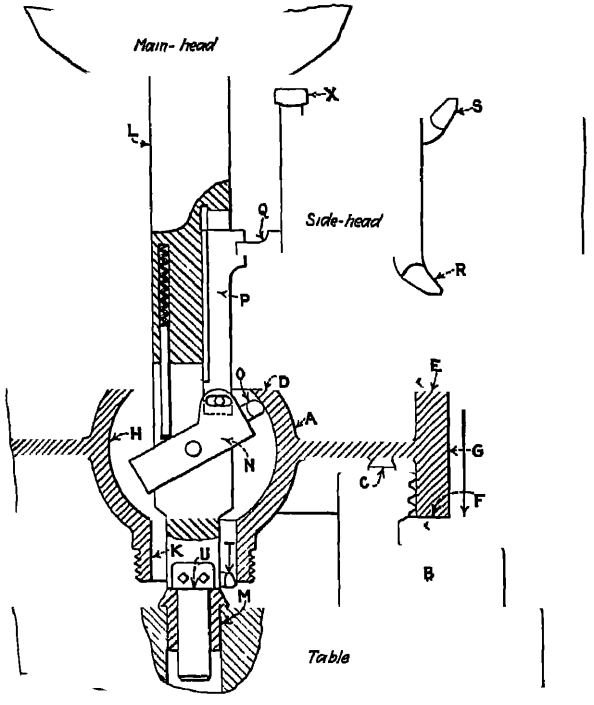


FIG 193 —Spherical boring attachment.

have been described and the mechanical principles involved can be adapted to suit various types of machines.

Many of the principles brought out in the chapter which treated of the design of attachments for horizontal turret lathes, are equally applicable to use on vertical turret lathes and boring mills. The construction of the machine, however, is somewhat different so that the application of attachments varies considerably, although the general principles may be much the same. In addition, the cutting action is usually more severe and the

attachments must be built in a more substantial manner than those used on horizontal turret lathes.

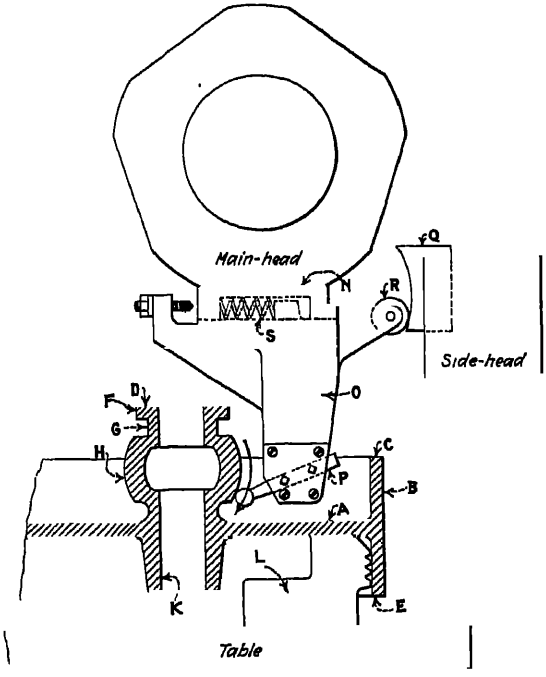
In Fig. 193 is shown a piece of work *A* which is held by the inside rough surface in a set of special chuck jaws *B*. The web of the casting rests on hardened buttons *C* in the chuck jaws. The work which is to be done consists of facing the surfaces *D* and *E*, turning the outside diameter *G* and undercutting the flange *F*. In addition to this machining, both the spherical hole *H* and the straight hole *K* are to be bored.

A heavy bar L is held in one of the turret faces and piloted at the lower end in a bushing *M* in the center of the table. The bar is slotted to receive a swivel block *N*, which carries a tool *O* for generating the spherical surface. Connected to the swivel block is a sliding member *P* traveling vertically in a slot in the side of the bar and operated by the finger *Q* in the sidehead. The feed is obtained by using the down feed of the sidehead. The cylindrical hole *K* is bored by a tool *T* in the lower end of the boring bar. This tool is so placed that it completes its work shortly before the shoulder *U* strikes against the top of the bushing. In using this tool the sidehead is disconnected and the turret feed used, the latter being thrown out of engagement at the completion of the cylindrical boring cut.

The surfaces *D* and *E* are faced by standard tools in the regular tool holders of the turret. The rough- and finish-turning of the outside diameter *G* is done by the sidehead, using the tools *R* and *S*, respectively. The undercutting of the flange *F* is also done by the sidehead, using the tool *X* for the purpose. The peculiar part of this equipment is the combination of a straight and spherical tool in the same bar, as this condition is seldom found. The tools *T* and *O* are both arranged so that they can be moved for roughing and finishing and other tools substituted rapidly.

Generating a Spherical Surface.—In Fig. 194 is shown a piece of work *A* which is to be turned at *B*, faced at *C* and *D*, undercut at *E*, turned at *F*, grooved at *G* and turned spherically at *H*. The hole *K* is also to be bored and reamed. All of these operations are to be done in one setting of the work, and as a consequence a considerable amount of special tool equipment is necessary. The jaws *L* grip the inside of the work in such a way that the tools in the sidehead used for undercutting will not interfere with the jaws. The table is provided with a central bushing which is used as a guide for the boring bars.

We are particularly interested in the turning of the spherical surface H, and the equipment for this purpose consists of a heavy casting N which is bolted to the face of the turret. On this casting a dovetailed slide O is mounted so that it is free to move longitudinally. The lower portion of this slide is built out so that it supports the tool P, which is used for turning the spherical surface. Both roughing and finishing tools are made so that they



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FIG 104.—Spherical turning attachment for vertical turret lathe.

fit the slide in the holder, so that one can be used after the other in the turning operation. The sidehead contains a form plate Q of the proper curvature, so that when the roll R is in contact with the curved surface the correct radius will be generated at H. A heavy coil spring S keeps the roller in contact with the form, and the down feed of the turret provides the power necessary.

Other tools are used in both turret and sidehead for performing the boring, facing, turning and grooving operations. The work shown here is rather unusual in shape, and because of the fact that the spherical surface is in such a position that it cannot

easily be reached by the sidehead tools, the design and application of a spherical turning device requires considerable ingenuity. In operation it was found that a fine feed was necessary in order to produce the desired finish.

Concave and Convex Surfaces.—If a vertical boring mill of the two-head type is used for manufacturing work, the generation of a curved surface causes considerably more trouble than if the work is done on a vertical turret lathe. Fig. 195 shows

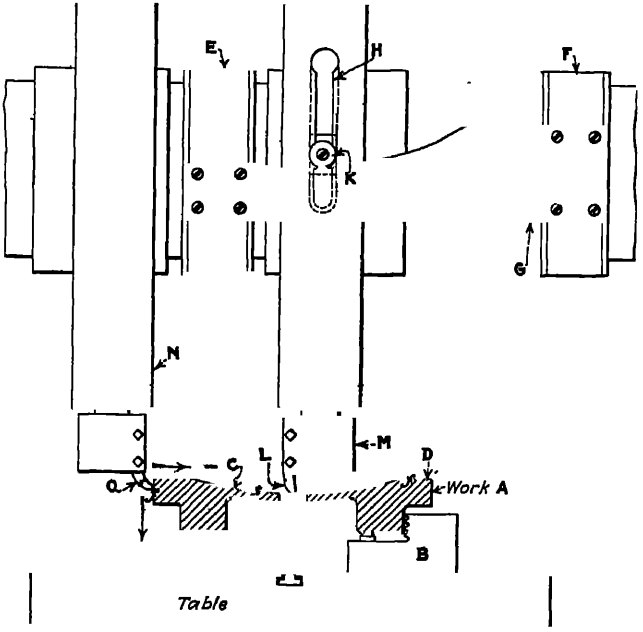


FIG. 195.—Spherical turning attachment for vertical turret lathe.

a piece of work *A* which is held in chuck jaws *B* in such a way that the curved surface *C* can be machined to the desired form, the plane surface *D* faced, and the outside diameter turned. It is desirable to perform all of these operations in the same setting and without loss of time. The work is set up in the jaws so that the under side of the flange rests on hardened buttons which are high enough so that the turning tool for the outside diameter will not strike the chuck jaws.

Two special brackets *E* and *F* are applied to the rails of the machine and on these brackets a form plate *G* is fastened. The

toolslide is slotted at H in a vertical direction, in order to permit the use of a block which carries a roller K. The block can be adjusted vertically in order to compensate for variations in the tool setting. In operation the tool L, held in a standard holder M, is controlled in its movement by the position of the roll K with respect to the form. When the feed is engaged the tool

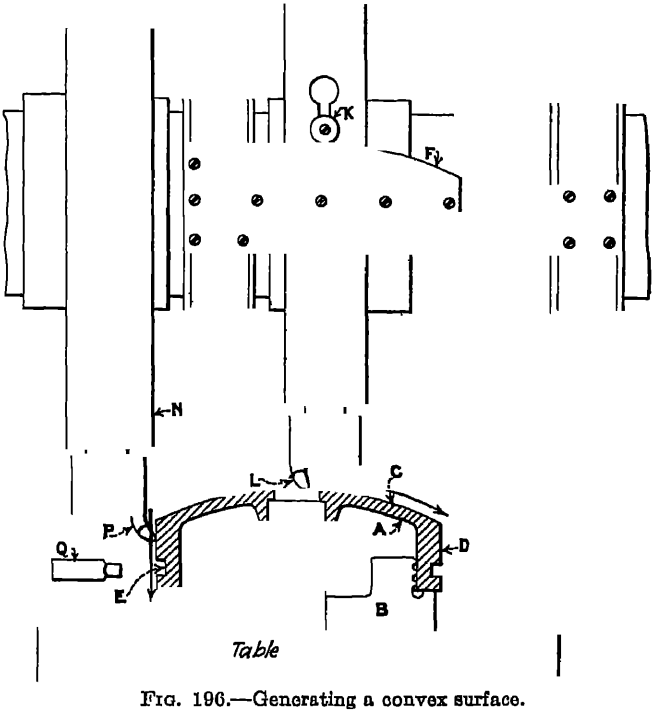


FIG. 196.—Generating a convex surface.

travels in the direction indicated by the arrow, thus generating the concave surface.

While this tool is in operation, the left-hand toolslide N faces the surface D and turns the outside diameter, the tool O being used for the purpose. This is a very simple arrangement, but it must be made substantially and carefully fitted to the machine. It also necessitates the removal of the right-hand toolslide in order to cut the slot in which the roller K is held.

The same attachment used for machining a convex surface is shown in Fig. 196, the only difference being in the shape of the form plate. The work A is held by the inside in a set of special

jaws B. The work which is to be done is facing the convex surface C, turning the outside diameter D and cutting the groove E. A form plate F is applied to the same brackets that have been shown in the previous illustration, and the roll K is adjusted to suit the conditions. The tool L is constrained to travel in the direction determined by the shape of the plate. While this operation is being done, the left-hand toolslide N is used to turn the outside diameter D with tool P. After the turning has been completed, the grooving tool Q is set in position and the groove E finished.

The various examples which have been given here are sufficient to illustrate the adaptability of vertical turret lathes and vertical boring mills to the machining of spherical surfaces. In addition to the devices illustrated, some of the ideas which have been mentioned under horizontal turret lathe work may in some cases be subject to a certain amount of revision and applied to vertical boring mill work. There are so many cases which require special treatment, that it is not considered advisable to take up here anything more than the simpler methods. Special attachments can, of course, be designed to suit particular cases. One point of importance is that, wherever possible, the attachments should be arranged so that the use of both heads will not be interfered with.

Layouts for Vertical Boring Mills.—In laying out tools for machining work on the vertical boring mill and vertical turret lathe, the standard tools which can be purchased with the machine are so adaptable that the tool layouts are considerably simplified. As there are only five sides to the turret there is less likelihood of interference, and the method of setting up the work and applying the tools allows the operator considerable latitude. In making tool layouts for the machines mentioned, a simple diagram like that shown in Fig. 197 will be found of great help. This diagram should be made in ink on tracing cloth, and should contain about as much information as seems to be essential for making a correct layout. The table diameter and the maximum movements of turret and sidehead should be clearly shown With the diagram as a guide, when it becomes necessary to make a layout the tools and tool holders can be easily placed in position, and the various operations indicated in such a way that they will be easily understood.

The first and second settings of a large cast-iron spider which is machined on a vertical turret lathe are shown in Figs. 198 and 199

All of the tools used for the operations are of a standard nature, and it is considered advisable to show these two settings in order to illustrate the adaptability of the machine to work of this character. The work *A* is held in standard jaws by the outside diameter and it rests upon hardened buttons *C*. The main head carries a standard type of boring bar *D*, in which tools *E* are used for rough- and finish-boring. The sidehead contains a tool *F*,

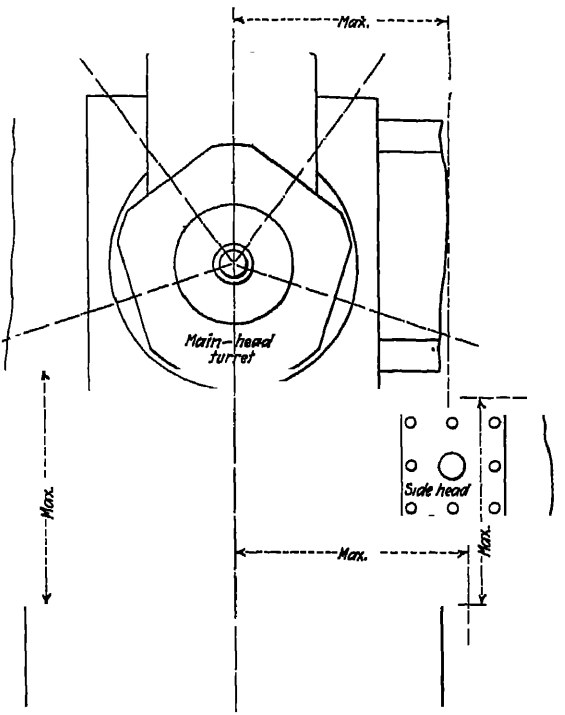


FIG 197.—Diagram for tool layouts on vertical turret lathe

which is used to face the hub and turn and face the other surfaces indicated by the arrows.

The sidehead and mainhead are working simultaneously. After the rough- and finish-boring operations have been done, the floating reamer blade *H* is placed in position in the bar *D* and the reaming cut taken, while the tool *G* in the sidehead is used to finish the same surfaces which were roughed in the first operation.

The second setting is shown in Fig. 199. The work is held by the outside in soft jaws *B*, which are bored out on the machine

to fit the outside surface finished in a previous operation. The work is supported on hardened buttons *C* in the chuck jaws. The tool *D* in a standard holder in the mainhead turret is used for roughing off the surface of the hub, a longitudinal feed causing the tool to travel in the direction indicated by the arrow. At the same time the tool *E* in the sidehead turret faces the flange, as shown by the arrow.

For the second operation, the tool *F* in the mainhead turret and tool *G* in the sidehead turret are used for finishing the same

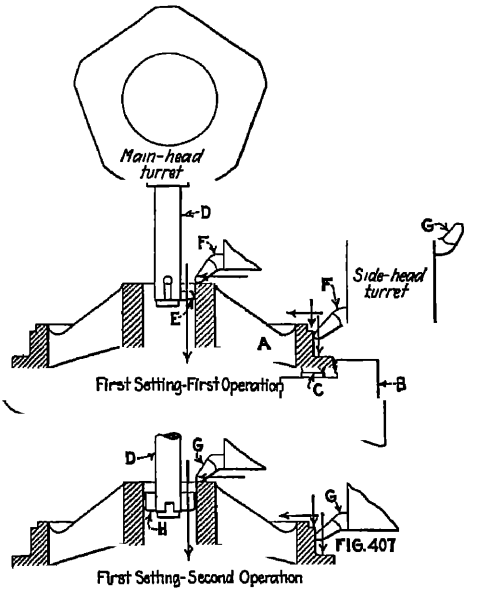


FIG. 198.—Tool layout using standard equipment.

surfaces. This completes the work and it will be seen that practically all of the tooling is of a standard nature. It can further be noted that both the mainhead and sidehead tools are working simultaneously and practically all of the time, which makes the production rapid.

We have several times mentioned the importance of keeping as many tools in operation at the same time as possible, in order to obtain maximum efficiency. This matter is exemplified on vertical turret lathe work, and the greatest care should be taken to make sure that the sidehead and mainhead turrets are working continuously, so far as the nature of the work will permit. At

he same time, it is often not necessary to go to great expense n regard to the tool set ups, but it does require that the engineer who makes the layout should be thoroughly familiar with the nachines and their movements if maximum production is to be obtained.

Holding a Large Piece.—In Fig. 200 is shown a piece of work *A* which has a diameter of 26 in. and which is to be machined on the

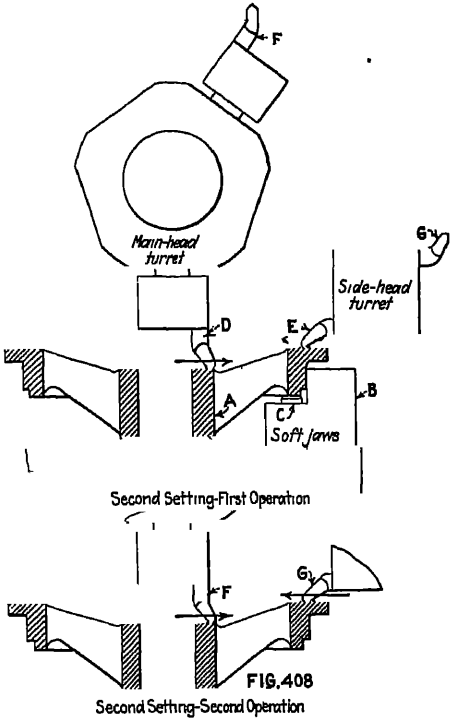


FIG. 199.—Second setting layout with standard tools.

various surfaces indicated in the illustration. The work is held by the outside in chuck jaws *B* and supported on hardened buttons *C*. The tool equipment used is very simple, and for a great part of the diameter both the sidehead and mainhead turrets are working simultaneously. In the first operation a standard tool holder carries tools *D* and *E*, which are used for rough-facing the surfaces indicated by the arrows. The turret is fed in a horizontal direction to produce this result. The tool *F* held in the

sidehead turret is at the same time fed inward in order to rough-face the surface shown.

In the second operation, the tool *G* is used for rough-boring

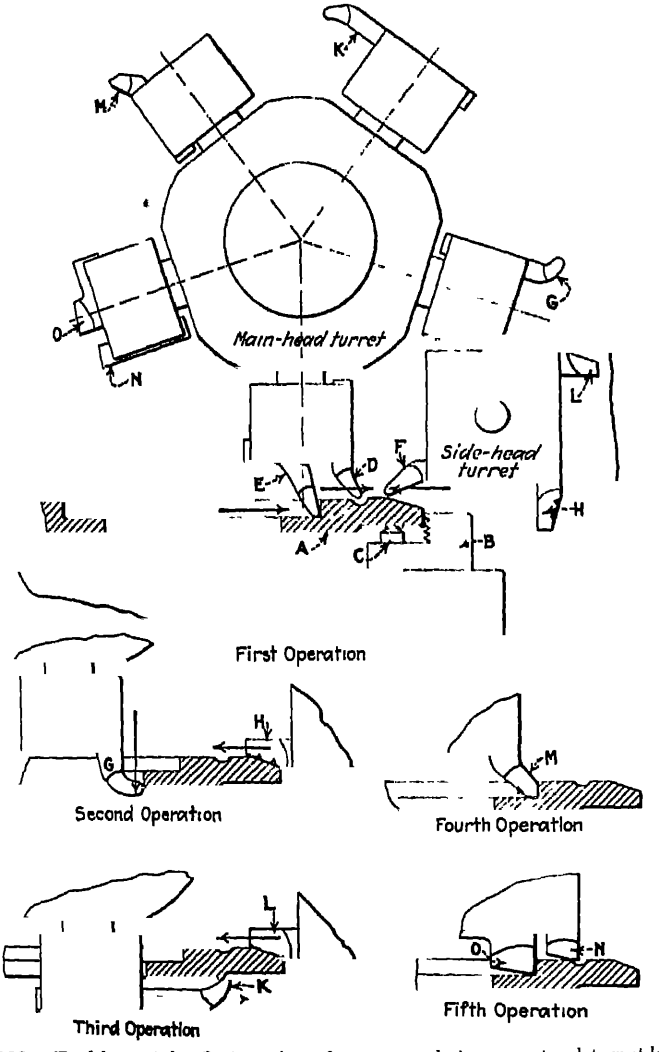


FIG. 200.—Tool layout for first setting of cast-iron disk on vertical turret lathe

the large hole, and the tool *H* in the sidehead turret is brought forward to rough-face the angular surface. The tool used here is nickeled, in order to break up the chip and make the cutting

action easier. In the third operation, the tool K is of exceptional length, but it is held in a standard tool holder as indicated. The mainhead turret is fed down to a predetermined distance and the tool K is used to undercut the surface shown. Only one roughing cut is taken on this surface. While this undercut is going on, the tool L in the sidehead turret is used for finishing the angular surface.

In the fourth operation the tool M finishes the shouldered portion of the work, leaving a small amount for a final sizing cut. The final finishing operation is done in the fifth operation by the tools N and O, these being so set that they will retain the shoulder distance, which is important.

The second setting of this piece is not shown, but it is very simple, and some of the same tools can be used that are shown in this illustration. The work is turned over and located on the finished shoulder on a special fixture of simple design. The outside diameter is then turned by the sidehead and the facing cuts done by the main head. No extra tools are necessary for this operation.

Layout for Piston-Ring Pot.—The work shown at A in Fig. 201 is a cast-iron ring pot of special form from which large packing rings are made and cut off. The tool required for such a piece of work is comparatively simple, yet the operation is somewhat different from any which have been previously described. In the first place, the lower portion of the casting B is made somewhat heavier than the remainder of the pot, and it is beveled as shown so that it can be firmly held in the special jaws C, which are cut to a corresponding angle. As this work is of 12-in. diameter and as the walls of the casting are rather thin, care is necessary in the cutting to make sure that excessive vibration is not set up by the tools. In order to prevent this vibration a special toolholder D is used in the mainhead, and it carries a boring tool E which works directly opposite a turning tool F in the sidehead. This method of machining tends to reduce vibration and greatly facilitates the cutting action.

The finishing of the outside and inside diameters is accomplished in the same manner by means of the holder G and tool H in the mainhead turret, working in opposition to a finishing tool K in the sidehead. After these two operations have been completed, the holder L is indexed into position and the roll M brought into contact with the inside of the ring pot.

The three tools *N*, *O* and *P* in the sidehead are now used for cutting off the ring, and the support furnished by the roll *M* is of value in order to prevent chatter. The parting tools mentioned are set progressively, so that *P* is slightly ahead of *O* and *O* is ahead of *N*. By this means the rings are cut off one at a time and the operator stops the machine and removes each ring as fast as it is made. It is possible to use more parting tools if desired, but it has been found that greater satisfaction is obtained

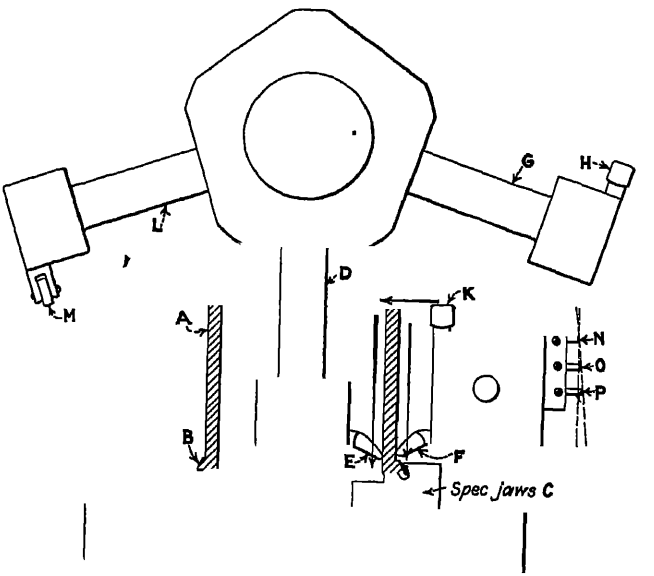


FIG. 201.—Tool layout for piston-ring pot.

by using two or three tools than by attempting to cut all the rings at one time. It is obvious that the roll *M* must be moved downward into a suitable position for giving support, according to the position of the sidehead tools.

We have attempted to cover in a concise and graphic manner the field of manufacture to which the vertical turret lathe is adapted, but the tool engineer will appreciate the fact that many of the matters which have been dealt with in horizontal turret-lathe tooling are applicable to the methods for the vertical turret lathe. For this reason it has been our endeavor to simplify the examples given as far as possible, in order to avoid any repetition of principles which have been previously treated.

CHAPTER XVI

FIXTURES FOR GRINDING

PRINCIPLES INVOLVED AND POINTS OF DESIGN—METHODS OF HOLDING FOR OUTSIDE CYLINDRICAL GRINDING—USE OF ARBORS AND STEADY RESTS—METHODS OF HOLDING FOR EXTERNAL, INTERNAL, DISK SURFACE AND FORM GRINDING —STANDARD AND SPECIAL FIXTURES AND MAGNETIC CHUCKS

The process of grinding is now used as a production operation to a considerable extent, whereas a few years ago it was considered more adaptable for accurate finishing operations after work had been hardened. For the removal of metal it was considered too slow a process to be of great value; but modern practice and the development of abrasives, together with the use of specialized machinery, shows a tendency toward the use of grinding as a production process. For the removal of considerable metal, grinding is not generally used, yet it is often found profitable for surfacing rough castings or forgings when a suitable finish allowance has been made. The tool designer must become familiar with the process of grinding and the machines used in order to thoroughly understand its applications to production work.

A few examples which illustrate the application of the grinding wheel to the work in different kinds of grinding are shown in Fig. 202. The diagrams are fundamental and are intended only to illustrate the principles involved in the grinding process. In the example *A* the work is cylindrical; it is held between the centers *B* and *C* and a suitable driver provided at *D*. The wheel *E* is applied to the work as indicated and the table *F* is reciprocated backward and forward while the work is being revolved.

The wheel is fed in to the work a little at a time until the desired diameter is reached. It is customary to use comparatively heavy roughing cuts until the diameter has been reduced to a size slightly greater than that required, after which fine feeds are used in order to produce the required finish. The type of wheel and the quality of the abrasive are determined by the nature of the work, and it is not our purpose to go into detail in

this regard. The tool engineer who is of an inquiring turn of mind can readily obtain the necessary data on grinding wheels by referring to manufacturers' catalogs.

In the example shown at *G* the work is held by the outside in chuck jaws *H*. The work to be done is grinding the inside

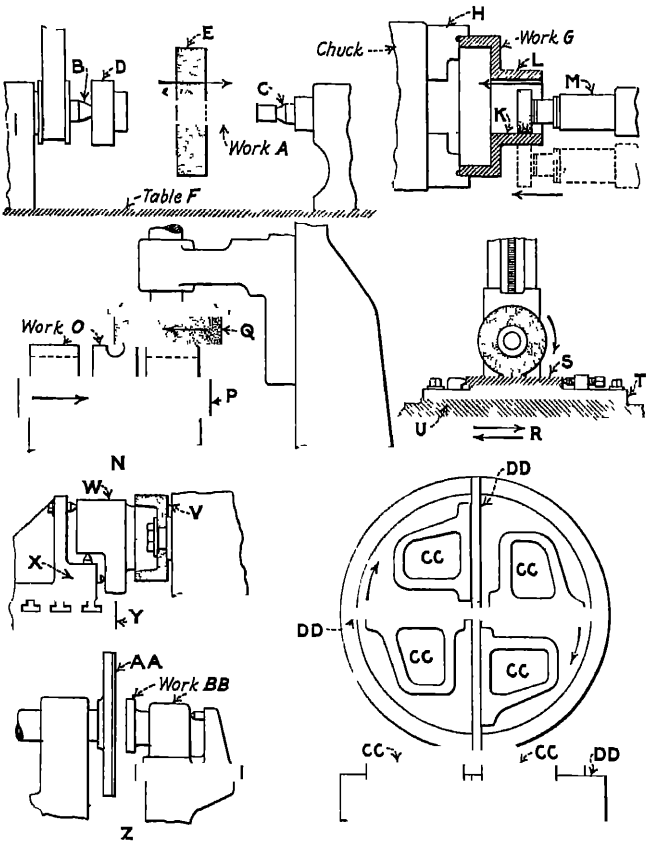


FIG. 202.—Examples of grinding operations.

surface *K* and the outside of the hub *L*. An internal grinding spindle *M* is applied to the machine, and suitable adjustments are made so that this spindle can take the positions shown by both the solid and dotted lines. The machine used may be a plain or an internal grinding machine.

A method used for surfacing either rough or finished work is shown at *N*. In this application the work *O* is held on a magnetic

chuck *P*, which is so arranged that it revolves under the wheel *Q*. This wheel is usually of the cup variety, and it comes in contact with the work as the latter revolves. Fixtures can also be used on this type of machine if the nature of the work requires it.

Another method of grinding surfaces is shown at *R*. Here the work *S* is held in a fixture *T* or on a magnetic table, as may be found desirable. The table *U* reciprocates in the direction indicated by the arrows while the work passes under the wheel. The feed, which can be operated by hand or power, causes the table to move transversely under the wheel a little at a time. This type of grinding machine is more generally used for tool-room work than for manufacturing.

Still another type of machine uses a cup wheel *V* mounted on a horizontal spindle, and the work *W* is held in a fixture *X* which is mounted on the reciprocating table *Y*.

Any mention of grinding processes would not be complete without an example of disk grinding, which is shown in the illustration at *Z*. Machines for this kind of grinding are made with a single spindle, which carries a faceplate *AA* on which an abrasive disk is mounted. The work *BB* is held against this surface while the disk revolves, thus removing the stock and leaving a smooth finish. Another type of disk grinder uses two spindles which are opposed to each other, and the work which is to be surfaced is passed between them so that the grinding effect takes place on both sides of the work at the same time.

Another method of disk grinding is by means of a large abrasive plate lying in a horizontal plane and revolving swiftly. Castings such as those shown at *CC* are laid on the disk, and their own weight holding them in contact with the abrasive surface is sufficient to cause removal of the stock with considerable rapidity. Suitable crossbars *DD* can be placed across the disk, and against these bars the work is thrust in the direction of rotation, as indicated by the arrows.

Turning and Grinding.—Fixtures which are used for turning and grinding are quite similar in their general features of construction; but the latter types are usually considerably lighter and the work does not need to be clamped as securely, because the removal of stock by the process of grinding is slower and does not tend to throw the work out of its position. In order to illustrate this point clearly two examples are shown in Fig. 203, in which a turret lathe fixture *A* is compared with a grinding fixture *B* for

the same piece of work. In the example *A* the work *C* is located on a plug *D*, which is set in the fixture *E* bolted to an adapter *F*, the latter being screwed to the spindle. The work rests on studs at *G* and is clamped down by straps *H*. The construction of this fixture is fairly heavy because tools are used for removing stock, as shown at *K*, and the hole *L* is also bored in the same operation.

In the example shown at *B* the fixture *M* is very much lighter and is screwed directly to the spindle of the machine. A locating plug *N* centralizes the work, which rests against three points *O* and is clamped in place by light clamps *P* operated by thumbscrews *Q*. Protection is afforded the operator by placing the

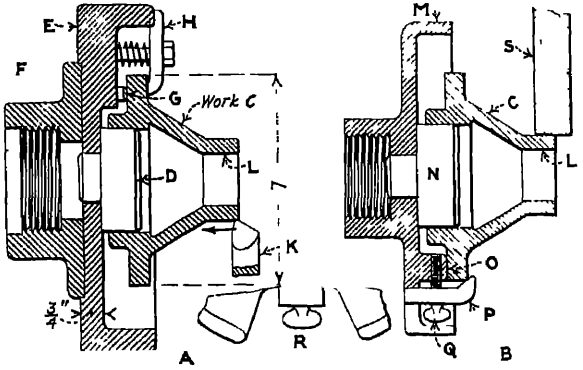


FIG. 203.—Turning and grinding fixtures for a flange

thumbscrews in the position shown by a detailed view at *R*. The wheel *S* is used on the outside of the work and an internal grinding attachment is applied for boring the hole *L*. The general construction of this fixture is much lighter than that used for the turret lathe, and the clamping is done by finger pressure. This illustrates the difference between the types of fixtures used for turning and grinding, but it should always be remembered that any fixture used on a grinding machine must be heavy enough so that it will support the work properly and not be subject to vibration.

In the grinding of shafts or other cylindrical pieces which are located on centers, there is very little for the tool engineer to concern himself about. There are occasional cases when a little ingenuity may be required to assist the grinding machine operator in setting up the work in order to obtain maximum production.

In the example *A* shown in Fig. 204 the work is a shaft 5 in. long by 1½ in. in diameter. If it were possible to grind this piece by employing the methods used in turning, one end would be driven positively and the other held on a center point. If the standard type of "dog" is used, the work can be ground only up to a point close to the dog. In order to complete the shaft, the

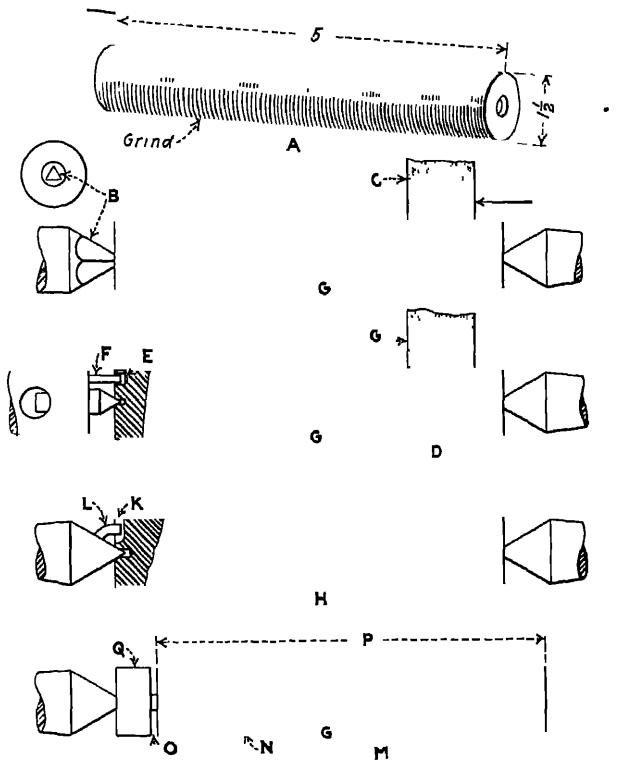


FIG 204.—Holding cylindrical work.

work would need to be reversed and the dog placed on the other end, after which the second grinding operation would have to be done very carefully in order to avoid a shoulder where the second cut overlaps the first.

One method of preventing this trouble is to use a special triangular center point like that shown at *B*. This center can be forced into the end of the work with sufficient pressure so that it will transmit torque enough to drive the shaft against the friction of the grinding wheel *C*. Another method which can be used for

a similar piece of work is shown at *D*. Here the shaft is centered in the usual manner and a hole is provided at *E* in which the pin *F* enters. This pin exerts sufficient pressure to drive the work against the thrust of the grinding wheel *G*. Another method which will give good results is shown at *H*. The work is slotted at *K*, so that the pin *L* will enter the slot and act as a driver. Still another method which is quite frequently used for small pins is shown at *M*. Here the work *N* is made somewhat longer than required and grooved deeply at *O*, so that the distance *P* is the length of the piece when finished. The additional stock at *Q* provides sufficient surface so that a "dog" can be applied to it for driving purposes. After the portion *N* has been ground to size, the end *Q* is broken off.

Straightening Work before Grinding.—When shafts are to be hardened and subsequently finished by grinding, a certain amount of stock is left on the work after the turning operation. It is quite possible that this "grinding allowance" does not take into consideration the possible warping of the work when hardening. It is seldom that a shaft of any great length can be hardened without a certain amount of distortion, and it is therefore necessary to straighten it preliminary to the grinding operation.

In order to illustrate this point clearly a diagram is shown in Fig. 205 in which the work *A* is a shaft which has been hardened, and which is found to have taken the position shown by the dotted lines at *B* and *C*. If an attempt were made to grind it in this condition, it would be impossible to reduce it to the proper size unless a very great amount of finish has been allowed for the grinding operation. In order to avoid the need for such a large allowance, the work should be straightened after hardening and before grinding. The usual method for a shaft is to place it on supports *D* and *E* and apply pressure to a block *F* by means of a suitably placed screw. The pressure can be applied by means of a handwheel or a lever, according to the requirements of the work. It will always be found necessary to depress the work considerably beyond its true center, as shown by the dotted lines at *G*, in order that it may spring back and return to a true position.

This example shows the importance of allowances for grinding The sizes are usually determined by the engineering department, and the shaft should be marked with limits for both turning and grinding. It is essential that the tool engineer should be very

careful to make all jigs and fixtures to the sizes which are produced by turning and not to the finish grinding sizes. If an occasion should arise where the grinding allowance does not appear to be sufficient, the matter should immediately be taken up with the engineering department and proper tolerances set.

Various types of steadyrests are used for supporting cylindrical work while grinding. The designs are somewhat different in their general features of construction, but the principles employed are much the same. In order to illustrate the application of steady-

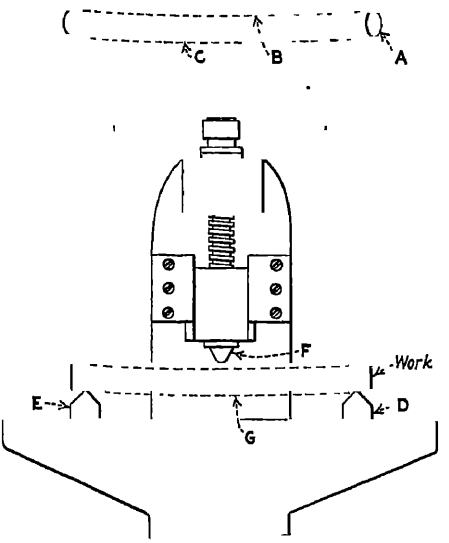


FIG. 205.—Straightening work before grinding.

rests to cylindrical work, we have shown a few examples in graphic form in Fig. 206. The shaft shown in section *A* is to be ground cylindrical by the wheel *B*, which revolves in the direction indicated by the arrow. The thrust of the grinding therefore is both downward and outward from the wheel. In order to counteract this thrust and provide sufficient stability to the shaft during the grinding process, a simple steadyrest such as that shown at *C* can be used. This rest can be made of wood, if desired, and mounted so that it can be adjusted to give the necessary support.

In the example *D* the wheel *E* acts in the same manner as that previously mentioned, but two supports *F* and *G* are provided for

the work. The lower support G obtains a contact with the work slightly ahead of the center, so that the action of the wheel has a tendency to hold the work firmly against both members F and G. These members are adjusted separately to suit the shaft diameter.

In the example H another type of rest K is used. The steady-rest is made in one piece and proportioned suitably to give the necessary stability. It has a contact with the work at L and M

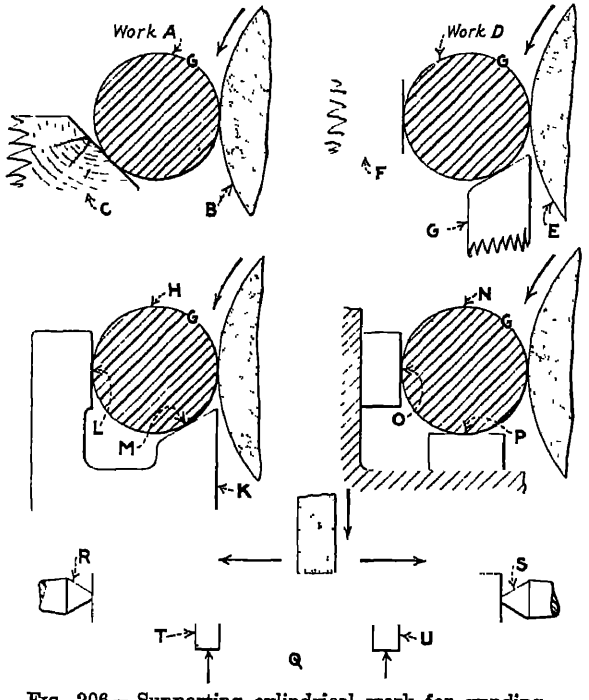


FIG. 206.—Supporting cylindrical work for grinding.

very similar to that previously mentioned. Another type, shown at N has two adjustable members O and P which are mounted so that they can be very easily brought into contact with different diameters of work.

In grinding long work several steadyrests may be necessary, and in order to secure accuracy the position of the steadyrests should be as shown in the example Q. The work is supported on centers at R and S, and two steadyrests T and U are placed in such a position that the support is equally distributed along the length of the shaft, the distances between the steadyrests and

centers being approximately the same. This is an important matter when setting up a shaft for grinding, and if considerable care is used when placing the steadyrests much better results will be obtained.

Points of Design.—Many of the principles which have been previously described can be applied equally well to the design of fixtures for grinding, and the cautions which have been given in regard to other types of fixtures should be reviewed and applied here. A few additional points should be given because the action of a grinding wheel is somewhat different from that of a cutting tool.

(1) Stability of fixture and proper balance are important factors in design. Vibration causes chatter which makes it impossible to produce good work in either turning or grinding. Therefore, the greatest care must be used to make sure that fixtures are sufficiently rigid and well balanced, so that they will not set up vibrations in the work or the machine. In grinding, the fixture revolves slowly while the wheel turns rapidly, and it may seem to the designer that with such comparatively slow movement the balance of the fixture is not important. It will be found, however, that any holding device which is considerably heavier on one side than on the other will be likely to produce inaccurate work. Therefore, when such a condition is found, the defect should be counteracted by the use of a counterpoise.

(2) The location of the work is important, as it is in all fixtures, and due to the fact that abrasives are being used continually there is a great deal of such matter that finds its way into the fixture. Consequently, locating surfaces and plugs are likely to lose their size quite rapidly on account of the abrasive action, so that they should be made replaceable if good results are to be obtained. If indexing pins are used great care must be taken to protect them, so that they are not subject to the action of the grinding dust.

(3) The method of holding the work in grinding fixtures is the same in principle as that used for fixtures for turret lathes and other machines of a similar kind. The amount of stock removed by the grinding wheel is much less than when turning or boring, and there is consequently less pulling action which tends to displace the work. Therefore, it is often possible to use spring clamps or even springs to hold the piece in position. Many times magnetic chucks are used in certain kinds of grinding, the holding

power of the magnets being sufficient to withstand the pressure of the grinding wheel.

(4) Work may be ground either wet or dry, depending on conditions. In the case of fixtures used for wet grinding, provision should be made so that the water can run out of the fixture freely. This is a very small matter and yet it should receive consideration when designing fixtures. There may be occasional cases where a special application will be found necessary in order to direct the stream of water into the proper position.

A few examples of simple arbors used for holding work while

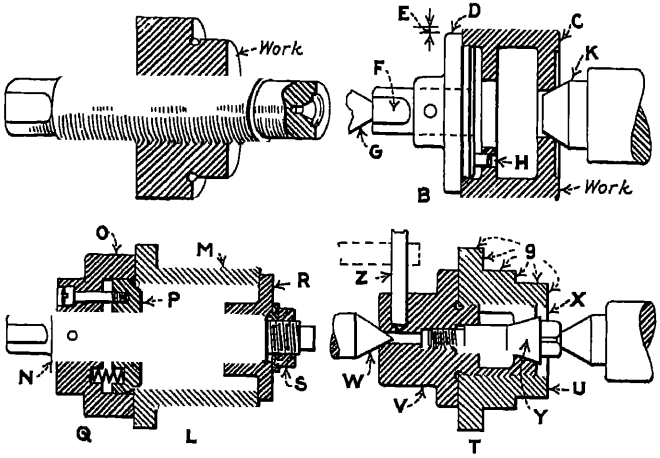


FIG. 207.—Plain arbors for cylindrical work.

grinding are shown in Fig. 207. The diagram of *A* is a plain taper arbor of the standard type, such as commonly used for turning cylindrical work. The example *B* shows a piece of work *C* mounted on a shouldered collar *D*, the outside diameter of which is slightly smaller than the finished outside diameter of the work, as indicated at *E*. The collar is pinned to a short arbor *F* which locates on the center *G*. The work is driven by means of a pin *H* entering the hole as shown. The outer end of the work is supported on the center *K*.

Another method of locating and holding is shown at *L*, in which example the work *M* has been previously finished. The arbor *N* has a collar *O* pinned to it, and a taper locating plug *P* is mounted by means of springs *Q* so that it forces itself into the end of the work, thus giving the central location. The collar *R* at the other

end of the piece is clamped in place by means of nuts and washers at S, which action draws the work back against the face of the collar O. The centers in each end of the arbor hold it in position for the grinding.

A simple type of expanding arbor is shown at T. The work U requires grinding operations on the various surfaces and shoulders as indicated by the arrows. The arbor V has a center W in one end, while the other is split at X in three places and expanded by

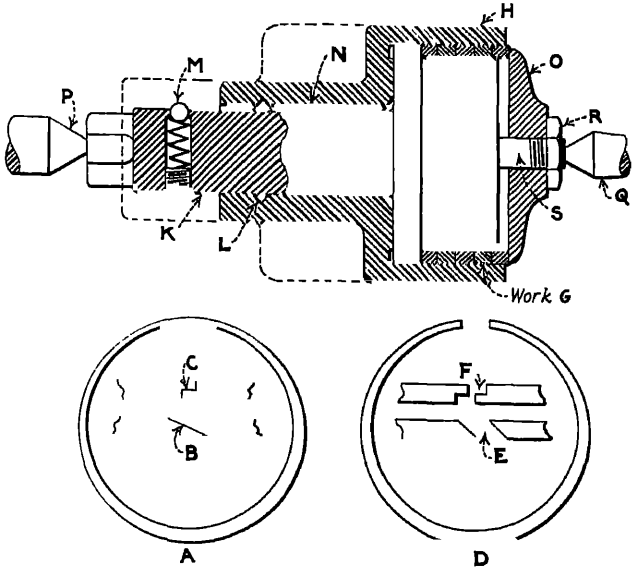


FIG 208.—Arbor for grinding eccentric piston rings.

means of the screw Y. A similar arbor to this has been described in the chapters on turret lathe work. The method of driving is by means of a pin Z which lies against a projecting stud in the face-plate. All of the arbors shown here are of very simple type, and it will be evident that there is considerable similarity between them and arbors used for machining operations.

Eccentric piston rings such as those used in automobile and other gas-engine cylinders must be ground on the outside diameter after they have been cut apart. In the example at A in Fig. 208 two methods of cutting the ring are shown. The example B is the ordinary form, in which the edges of the ring come together on a diagonal line. The lap-joint ring shown at C is

another form, which is not so commonly used. In machining rings of this kind, they are bored and then turned eccentrically, after which a piece of each ring is cut out, as shown at *E* and *F* in the example *D*

When grinding the rings, they must be closed up and drawn together so that the edges meet, and they must be held in this position during the process of grinding A method of holding frequently employed for this kind of work is shown in the same illustration. From four to six rings *G* are sprung together and placed in the shell *H*, which is mounted on an arbor *K* so that it is sliding fit. The collar *O* is brought up against the edge of the outer ring and clamped in place by the nut *R*. The stud *S* is centrally located in the body of the arbor and contains a countersunk portion in which the center *Q* locates. The other end of the arbor rests on the center *P*.

After the rings have been placed in position and the collar tightened, the operator pulls the sleeve *H* back as indicated by the dotted outline. This leaves the rings clear, so that the grinding wheel can be used to finish the outside diameter. The arbor is furnished with a ball *M*, which acts as a "detent" in the groove *L* when the sleeve is pulled back from the rings. A point of importance in connection with the design is the groove *N*, which is used solely for the purpose of relieving the air pressure when moving the sleeve backward and forward on the arbor. Unless some provision for this relief is made, great difficulty will be experienced on account of the close fit.

When work has been previously finished, a collet or fixture of some kind is often found necessary. There are some cases where a chuck can be used to hold finished work for grinding, although for a great deal of work the chuck is not accurate enough to produce first-class results. Fig. 209 shows several methods of holding work which has been previously machined. The example at *A* shows a piece of work *B* held in a collet at *C*. This collet is tapered at *E* so that it fits a corresponding taper in the nosepiece *D*. It is drawn back into position so that it grips the work firmly, by means of a rod which extends back through the spindle as at *F*. In grinding the hole an internal grinding attachment is used, with a wheel as shown at *G*.

For certain kinds of work the method of holding just described will be found satisfactory, although in many cases a collet can-

not be considered sufficiently good to produce absolutely accurate work. In the example *H* a piece of thin work *K* is to be ground internally by the wheel *O*. The work locates in a hardened collar *L* which fits it accurately. In order to avoid distortion, the pressure necessary for holding the work is exerted entirely on the end of the piece by means of the clamp *N*, which is bored out to a diameter sufficiently large to allow the grinding wheel spindle to enter. The studs which hold the clamp in place are two in

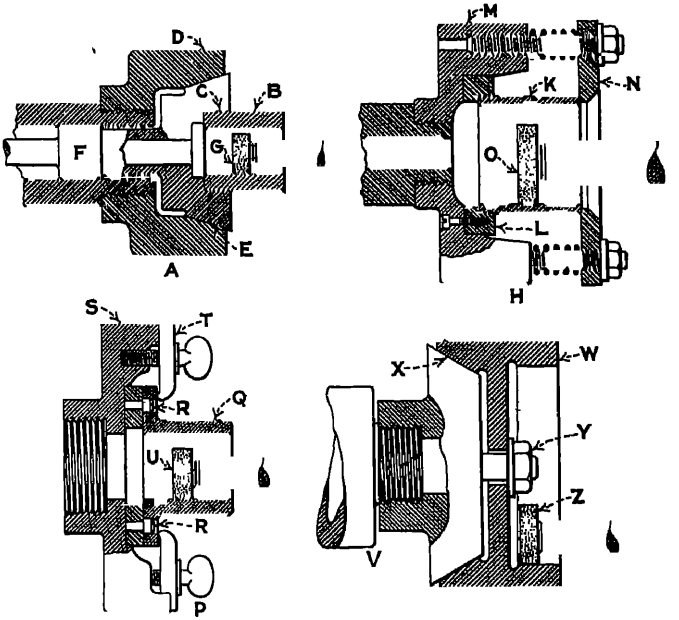


FIG 209 —Methods of holding work for grinding.

number, and they are inserted in the body of the fixture *M* as shown. For light work the clamp can be set up by means to thumbscrews instead of the nuts. By bringing pressure of bear in this way on the end of the work there is very little danger of distortion, and therefore a piece of work which is thin can be clamped firmly enough to allow the grinding to take place.

In the example shown at *P* the work *Q* is to be ground internally by the wheel *U*. The method of location in this case is by means of the pins *R*, which are set in a hardened ring against which the work is clamped by means of the straps *T*. These straps are operated by thumbscrews as indicated. The fixture

S is screwed directly to the spindle of the machine. In rare cases this method of holding may be found satisfactory, but it will seldom be so unless great accuracy has been maintained in the previous operations, and unless the locations for these operations have been made from the same holes. There are instances when a piece of work must be ground on the inside after the outside has been finished; and when a subsequent grinding

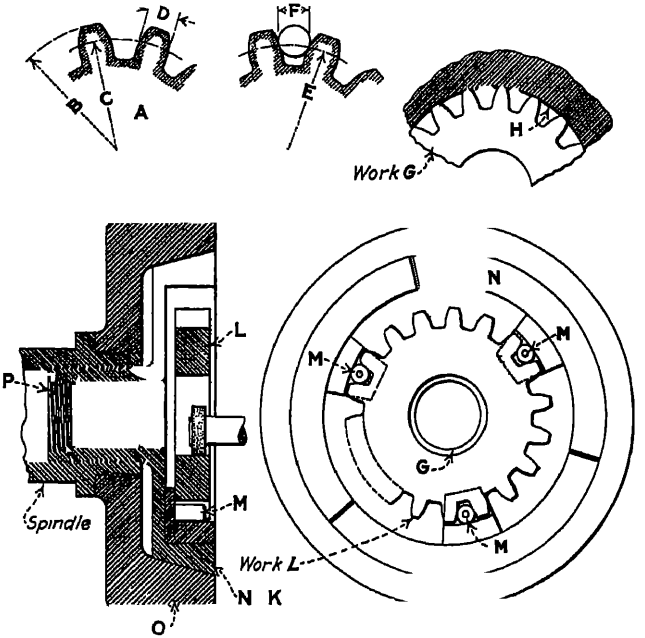


FIG. 210.—Locating spur gears for grinding.

operation for the outside surface is necessary, the hole can be ground first and the work placed on an arbor for the second grinding operation with the assurance that a concentric job will result.

The example at V shows a piece of work W which has been previously machined on the angular surface X, and it is necessary to grind the other side concentric with the angular portion. The work is located on a taper plug at X and is clamped by means of the nut and washer at Y. The grinding is done by an internal grinding attachment, using the wheel Z. This is a very simple fixture and the only points of importance in connection with it

are the clearance for the grinding wheel spindle and wheel and the method of clamping. This particular case permits a center clamp, but other instances may be found where such a means may not be possible, in which case a special method may be found necessary.

In order that a spur gear may run true after it has been hardened, it is usually considered necessary to grind the center hole. Many times the process of hardening distorts the gear to some extent, so that the teeth do not run perfectly true with the hole. A portion of a spur gear is shown at *A* in Fig. 210. The outside diameter *B*, the pitch diameter *C* and the thickness of the tooth *D* are subject to a certain amount of change during hardening. In order to locate the hole so that it will be central with the pitch line of the gear, pins are placed between the teeth as shown at *F*. The distance *E* from the center of the gear must be determined and maintained with care. The diameter of the pin should be such that the pin will strike the tooth directly on the pitch line, and as this point lies on a curved surface care must be taken to see that the pin is correctly proportioned.

In the example *G* the method of locating is by means of the outside diameter of the gear in a pocket *H*. This method is not usually considered good, as it may be found that the distortion will not allow the gear to locate properly so that the hole will be central.

The diagram at *K* shows the construction of a collet chuck for holding spur gears. The gear *L* locates on three rollers *M*, which are set in the collet *N* so that they will move inward or outward as the collet is contracted or expanded. The rollers may be three, four, five or six in number, depending on the number of teeth in the gear. They must be so placed that they will come in contact between the teeth and on the pitch line. The collet used is mounted in a nosepiece *O* which screws to the end of the spindle. The operation of the collet is by means of a closer which screws in to the end *P*. Various applications of this principle can be used for any work of a similar kind, and it is only necessary to design the holding device so that the contraction of the collet will cause the rollers to move inward in a truly radial direction.

In Fig. 211 is shown at *A* a bevel ring gear *B* in which the hole *E* must be ground so that the face *C* will run true with the

pitch line of the gear. In this case the work is located on three pins *D* and clamped against the hardened ring by means of springs which are applied to the angular face *C*. This method may be considered good, providing the locating surface has been previously ground from the pitch line of the gear, but otherwise there is likely to be trouble due to the warping of the angular surface during hardening.

A better way of grinding the hole is shown in the example at *F*. Here a master gear *G* which is accurately made is screwed to the face of the fixture and located centrally. On this master the

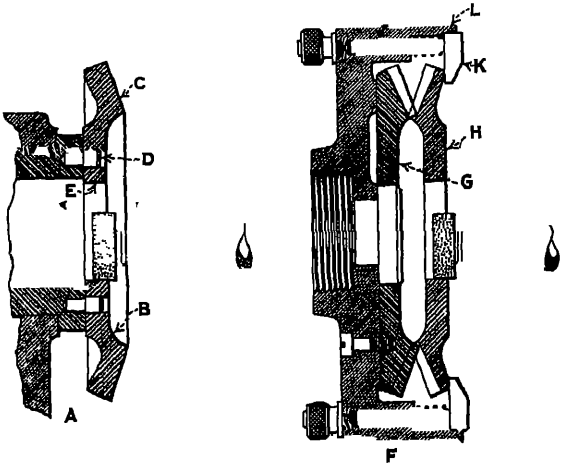


FIG 211.—Locating bevel ring gears.

ring gear *H* is located, being clamped in place by means of the hook bolts at *K*. This gives the pitch-line location, so that when the hole is ground it will be true with the pitch line of the gear. The hook bolts *K* are of light construction and in some cases springs can be used, although the latter must be very stiff unless the gear is of small size. The hook bolts can be operated by thumbnuts at the rear of the fixture *L*.

Cylinders for gas engines are often finished by grinding, and the machine used for the purpose has a spindle arranged horizontally and carried in eccentric sleeves, as shown at *K* in Fig. 212. Provision is made so that the eccentricity of the spindle can be adjusted, to take care of various diameters within the capacity of the machine. The type of fixture required for work of this kind is quite different from any which has been previously shown.

Sometimes the work is ground wet and sometimes dry, and provision may be made for the removal of the dust by a vacuum system. Usually the work *A* is held on an angle-plate fixture *B* and clamped against a surface perpendicular to the spindle of the machine. Very often the location is obtained by means of several pins, as shown at *C*, and the cylinder is clamped by some convenient method.

In the example a latch *D* is arranged so that it can be thrown down out of the way when not in use, and when in the position *E* a cam lever *F* locks it in place and at the same time forces the cylinder against the locating surface. The nature of the clamp

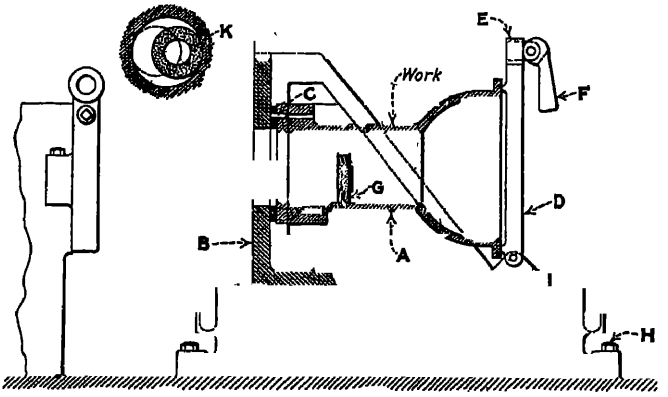


FIG 212.—Horizontal cylinder grinding.

used is dependent entirely upon the size and shape of the cylinder casting which is to be ground. In operation the wheel *G* is mounted on the end of a long spindle, and the table *H* is fed gradually along while the wheel is in rotation. As the spindle is mounted eccentrically, the path described by the wheel can be controlled so that a specified diameter can be obtained without difficulty.

Holding Work on Magnetic Chucks.—The diagram in Fig. 213 illustrates the use of magnetic chucks for holding work when grinding. In the example *A* the chuck *B* is arranged so that an electric current can be passed through its coils by closing a switch; and as the current is turned on the magnets are energized, so that they will pull and hold down on the surface any steel or iron parts which are laid upon the chuck. Many applications of magnetic chucks can be made to the process of surface grind-

ing, and in the example indicated a number of bushings *C* are grouped together on the chuck so that the ends can be ground by means of the cup wheel *D*. The chuck *B* revolves and is fed forward under the wheel when in operation.

Another type of magnetic chuck is more in the nature of a

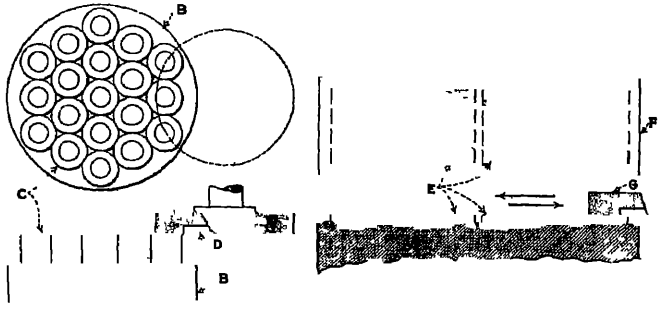


FIG. 213.—Holding work on magnetic chucks.

table, since it is rectangular in shape as at *F*. This type is also used for surface grinding, but the table reciprocates in the direction indicated by the arrows, so that the work passes back and forth under the wheel *G*. In grinding a group of flat bars such

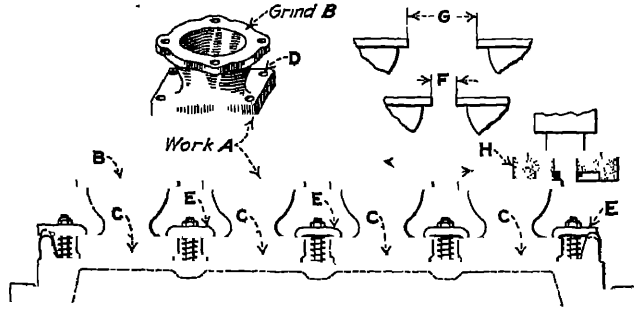


FIG. 214.—Fixture for horizontal surface grinding.

as those shown at *E*, the bars can be laid down on the magnetic table and held there by magnetism.

In extreme cases thrust pins can be suitably placed so that there is no danger of the work shifting while the operation is going on. This is not generally necessary, except in cases where a very small amount of surface of the work is in contact with the table. Magnetic chucks and tables are used extensively in

grinding operations, and occasionally a combination of the chucks with some method of locating work can be made. For example, if a location is needed so that work will be ground for only a certain portion of its width or length, suitable stops can be provided.

It is not always possible to hold work by means of a magnetic chuck, and yet a surface grinding operation may be required. A type of fixture used for work of this kind is shown in Fig. 214. The castings *A* are to be ground on the surfaces *B*, and they have been previously machined on the surfaces *C* and in the holes *D*. The surface *C* and holes *D* can therefore be used for location, and a fixture can be designed like that shown at *E*.

The bed of the fixture is long, and is arranged so that it can be fastened to the table of a horizontal surface grinding machine by means of T-bolts. The work locates on two pins in the holes *D* and rests on the surface *C*. It is clamped down by means of straps *E* at the ends and between the pieces. Fixtures of this kind are very simple in their general construction, although instances are found where the shape of the piece necessitates particular care in the location and clamping.

Care should always be taken to place as many pieces on the table as the diameter of the wheel will cover, and in locating the work the distance between the flanges should be as small as possible, always having in mind the necessity for ease in operating the clamps. It is much better to arrange the work so that the pieces will approach each other, as shown at *F*, rather than to have them spaced a considerable distance apart, as at *G*. The wheel *H* passes over the flanges of the work as the table reciprocates in the direction indicated by the arrows.

Disk Grinding.—The fixtures used for disk grinding are generally very simple in their design, as the work which is done is a plain surfacing operation. Fig. 215 shows a piece of work *A* in contact with a revolving disk *B* on which there is an abrasive substance. The surface which is to be ground is shown at *C*. The piece is held in a fixture *D*, located against pins *E* and clamped by some convenient method which can be rapidly operated. The table *F* is arranged so that it can be forced in against the work by means of a lever *G*, and at the same time it is pivoted on a shaft *H* so that it can be swung on this shaft as a bearing. A counterweight *K* balances the entire unit so that it is not topheavy.

The requirements of fixtures for disk grinding on machines of this kind are of the simplest. The method of holding must be developed according to the nature of the work, and it is essential to have a quick method of clamping. Aside from this the design of fixtures is along the same lines as those used for milling. The amount of metal removed, however, is comparatively small so that the pressure on the work is not as great as when milling.

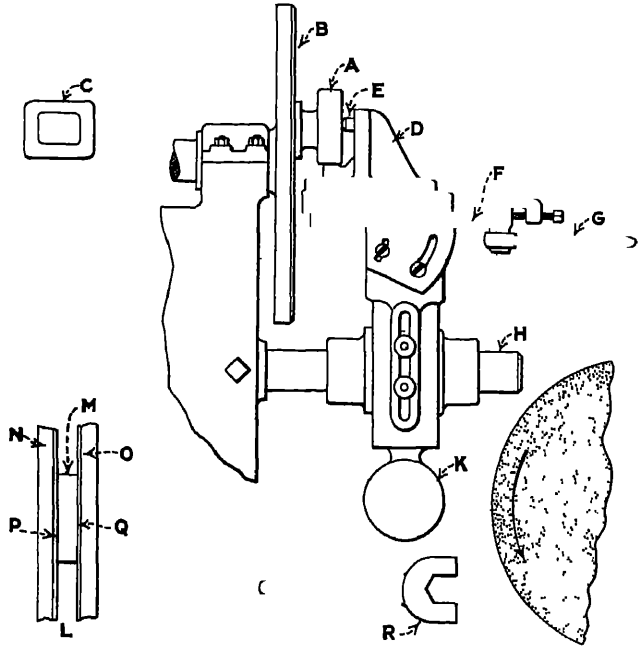


FIG. 215.—Examples of disk grinding.

The example mentioned is applied to a disk grinding machine having a single wheel; but it is often desirable to surface two sides of a given piece of work at the same time, and when this is the case the double-disk type of grinding machine is to be preferred. The diagram at *L* illustrates the action of the disks on a piece of work *M* which passes between the two disks *N* and *O* so that an abrasive action takes place on both sides at *P* and *Q*. The work is usually held on a slide so arranged that it can be passed between the two disks by means of a lever or handwheel.

Any fixtures used for work of this kind must be arranged so that the clamps will not extend beyond the edge of the fixture, as

otherwise they would interfere with the action of the disks. For work such as the wrench shown at *R* on which the two sides are to be surfaced, a double-disk grinding machine has many possibilities. There are no other points in connection with the design of fixtures for this kind of work which need comment.

Form Grinding.—In the grinding of forms of various kinds two methods are in common use. In one of these the wheel is "dressed" to the shape of the form required, while in the other the wheel is controlled in its movements by means of a form of suitable shape so that the desired contour is generated. Fig. 216 shows an example at *A* in which the work *B* is ground on the

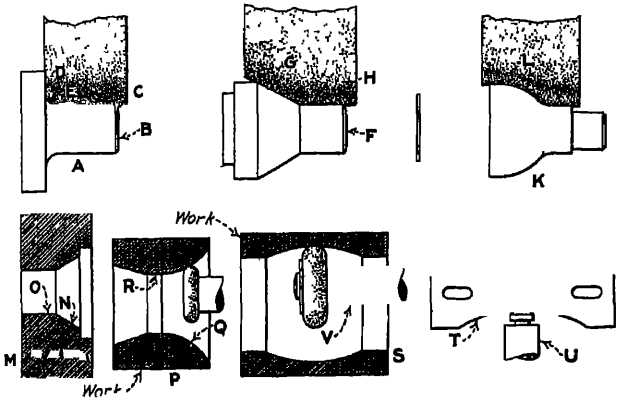


FIG. 216.—Principles of form grinding.

diameter *C*, the face *D* and the fillet *E* at the same time by means of a wheel which is shaped to the form shown.

Another example of a piece of work which can be handled by means of a formed wheel is shown at *F*. Here the wheel is formed to the angle *G*, and the portion *H* made straight so that both the angle and cylindrical portion are ground at the same time. In the form shown at *K* the work is of a curved contour, and therefore the wheel must be very carefully formed to the shape shown at *L* in order that the surface may be ground accurately and to the required dimension. These examples all illustrate the field which is covered by the process of grinding with a formed wheel. A cylindrical grinding machine is used for this work.

For the generating of surfaces either internal or external another type of machine is required, but two methods are possible on some of this work. For example, the piece shown at *M* is to

be ground on the taper at N and in the straight hole O. This work can be done by means of an internal grinding machine arranged so that the taper will be generated by the taper slide. After this has been done the slide can be set over to grind the straight portion O.

By using a type of machine which has a control or form plate, both surfaces can be ground in the same setting without any change in the position of the wheel or of the slide. Briefly stated, machines of this kind have a spindle which carries a grinding wheel and a follower which controls the position of the spindle. The form plate is made in accordance with the shape which is to be generated, and the follower rides on this plate, thus causing the wheel to produce the shape desired. A plate for the work shown at M would have a taper portion to correspond with that at N and a straight portion like that at O.

Another example, shown at P, has a curved portion Q running into a straight hole R. This work would be done in the same manner as that previously described, and the only difference would be in the shape of the form plate. In the example S the work has an internal curved surface running into a straight hole. The form of control plate used for this operation is indicated at T, the follower pin U controlling the movement of the spindle V to produce the desired contour.

To make sure that the hole is properly shaped, considerable attention must be given to the shape of the follower, in order that the generation may be correct as determined by the movement of the follower pin and the wheel. The proper shape of the grinding wheel periphery must be carefully laid out, and the plate formed in such a way that it will cause the wheel to travel in exactly the direction desired.

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